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A STUDY OF ORGANIC SET: IMMEDIATE REPRODUCTION, BY DIFFERENT MUSCLE GROUPS, OF PATTERNS PRESENTED BY SUCCESSIVE VISUAL FLASHES

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In everyday life one may receive a verbal instruction through the ear as in speech, or through the eye as in reading a letter, or through the sense of touch as in Braille printing. It does not much matter through which sensory channel an instruction is received; once a determining set has been established it normally persists until discharged in overt action.

When a central set has been established it can be released through a variety of motor channels. If, for example, I have learned a melody and am set to reproduce it, I can sing it, play it on the piano or on the pedals of an organ or on the xylophone, in this key or in that, etc. Different muscle groups are employed in these modes of reproduction. Again, if I have resolved to mail a letter, I can hand it to a friend with a verbal request that it be mailed, drop it in a letter box, hand it to the postman across the street, etc. Any one of these acts will remove the determining set.[1]

[1] Such terms as *set*, *disposition*, *attitude*, *determining tendency*, *posture*, *expectancy*, *excitation background*, *hypothesis*, and their German equivalents, are broadcast throughout the psychological literature. Instead of attempting the gigantic task of working out definitions and implications of these terms, a few recent references to general discussions are offered. The paper by Dashiell is recommended for orientation. Dashiell, J. F., A neglected fourth dimension to psychological research, *Psychol. Rev.*, 1940, **47**, 289–305; Freeman, G. L., The problem of set, *Amer. J. Psychol.*, 1939, **52**, 16–30; Woodworth, R. S., Situation- and goal-set, *Amer. J. Psychol.*, 1937, **50**, 130–140; Young, P. T., The phenomena of organic set, *Psychol. Rev.*, 1925, **32**, 472–478.

Since the present manuscript was prepared the following important paper has appeared: Gibson, J. J., A critical review of the concept of set in contemporary experimental psychology, *Psychol. Bull.*, 1941, **38**, 781–817.

In earlier studies [2] some of the factors which determine the ability of a subject to become temporarily set and to respond immediately on the basis of this set were investigated. Gundlach, Rothschild and Young flashed a small number (3 to 9) of lights in front of the subject, one after the other, and instructed the subject to grasp the pattern and reproduce it immediately by pointing to the positions where lights had appeared. They investigated the reproduction scores in relation to the age of the subject, the number of lights flashed, the speed of presenting the pattern, the amount of practice, and the complexity of the visual pattern formed by the flashes.

Later, Compton and Young [3] raised this question: How far does the ability of a subject to become set and to act immediately on the basis of this set depend upon the sensory mode through which the pattern is presented? In this experiment (which will be referred to as the Compton study) organic sets were established through seven modes of sensory presentation. In each trial a pattern was presented to the subject by successive stimulation at discrete points in his spatial field. Sometimes the stimulations were visual, sometimes auditory, sometimes tactual, sometimes mixed. These point-stimulations built up in the subject a determining set. Immediately after the presentation the subject reproduced the stimulus-pattern by pressing hand keys. His ability to reproduce a pattern was taken as evidence that a temporary set had been established and that this set determined the subsequent reaction.

The present experiment (which will be referred to as the Thomas study) is complementary to that of Compton and so closely related to it that the two will be considered together in discussing results. The present study centers around this question: How far does the ability of a subject to become set and to respond immediately on the basis of that set depend upon the motor system employed?

In the present investigation organic sets were established through a single sensory channel—vision. These temporary sets were expressed through three distinct muscle groups: (1) those of the arms and hands which were used to press hand keys; (2) those of the head and neck which were employed to press a special group of head keys; (3) those of the legs and feet, for operating pedals. On

[2] Gundlach, R., Rothschild, D. A., and Young, P. T., A test and analysis of 'set,' *J. exp. Psychol.*, 1927, **10**, 247–280.

[3] Compton, R. K., and Young, P. T., A study of organic set: immediate reproduction of spatial patterns presented by successive points to different senses, *J. exp. Psychol.*, 1933, 16, 775–797.

The present paper is based upon a doctoral dissertation which is in the Library of the University of Illinois: William Frederick Thomas, *A study of organic set: immediate reproduction, by different muscle systems, of patterns presented point by point to the eye*; Urbana, Illinois, 1939.

some trials a pattern was reproduced exclusively by one motor system; in some, by two motor systems used alternately; in some by all three systems in rotation. All told there were seven modes of reproduction.

In the following pages we will first describe the apparatus, procedure, plan of the series, data sheets and subjects. After this the main results will be given and discussed.

Conditions of Experiment

Apparatus.—The apparatus was planned to meet two main requirements. First, it was necessary to present the subject with a series of six flashes of light from different fixed positions. The flashes had to be of equal duration and to appear at a constant rate; the spatial and temporal sequence of light-flashes, moreover, had to be controlled by the experimenter. Second, it was necessary to provide hand keys, head keys and pedals by means of which a given pattern could be reproduced; and a system of signals through which the experimenter could observe and record the subject's performance in attempting to reproduce the patterns. A subordinate requirement was a device for informing the subject of the mode of reproduction to be used in a given trial.

The arrangements for meeting the above requirements are shown in Plates I and II. Numbers and letters were placed on the apparatus before photographing to aid in description. In the interests of clarity we will first consider the second of the above requirements.

The subject is seated on a chair directly in front of the table shown in Plate I. His head is located in the center of a semi-circumference which holds six head keys (*A, B, C, D, E, F*) all within easy reach of the forehead and temples. His hands can touch the six keys fastened to the table (*G, H, I, J, K, L*) which are used for signaling patterns manually. The feet rest upon pedals (*M, N, O, P, Q, R*); the three pedals at the left are controlled by the left foot and those at the right by the right foot.

In adjusting the apparatus the height of the chair is first regulated so that the pedals can be easily reached; then the head keys are raised or lowered to the proper position. Measurements are recorded for each subject and used throughout the experiment.

Wires from the head keys (*A, B, C, D, E, F*), shown in Plate I, lead respectively to the *tip* contacts of telephone jacks (*A, B, C, D, E, F*) in the control board pictured in Plate II. Similarly, wires from the hand keys (*G, H, I, J, K, L*), shown in Plate I, lead respectively to the *tip* contacts of jacks (*G, H, I, J, K, L*) in the control panel, Plate II. And wires from the pedals (*M, N, O, P, Q, R*) of Plate I lead respectively to the *tip* contacts of jacks (*M, N, O, P, Q, R*) of Plate II.

When a telephone plug is inserted into a jack the tip contact is then electrically connected to one of the electric lamps located just above the numbers *1, 2, 3, 4, 5, 6* shown in Plate II. For example, in the photograph the first of the six plugs is now inserted into jack *I*. With this connection the hand key located at *I*, Plate I, will light the lamp directly above the number *1*, Plate II; no other key or pedal which the subject can operate will light this lamp.

If the instruction calls for reproduction of a pattern exclusively by the head keys, all plugs are placed in the top row of jacks (*A, B, C, D, E, F*) in the specified pattern-sequence; then head keys and only head keys control the six lamps. If the subject reproduces the pattern correctly, the six lamps of the control board flash in order from left to right. If the instruction calls for reproduction of a pattern by hand keys, the plugs are placed in the second row (*G, H, I, J, K, L*); then only the hand keys control the lamps of the panel. Similarly, if the instruction requires exclusive use of the pedals, jacks in the lowest row (*M, N, O, P, Q, R*) are used; only pedals control these lamps. In some of the tests the subject is instructed to use two systems of keys alternately, as head and hand keys; the experimenter then places the plugs alternately in the appropriate rows of jacks. If the subject succeeds in reproducing the pattern as required, the lights on the panel flash in one-two-three sequence.

Next we will consider the device used to inform the subject of the mode of reproduction in a given trial. Directly in front of the subject at a point marked *X*, Plate I, is a rectangular window in which the word *HAND* appears. This instructs the subject to reproduce the next pattern with the hand keys exclusively. By means of a string and pulley the experimenter is able to raise the screen at *X* thus cutting off from view the rectangle in which the word *HAND*

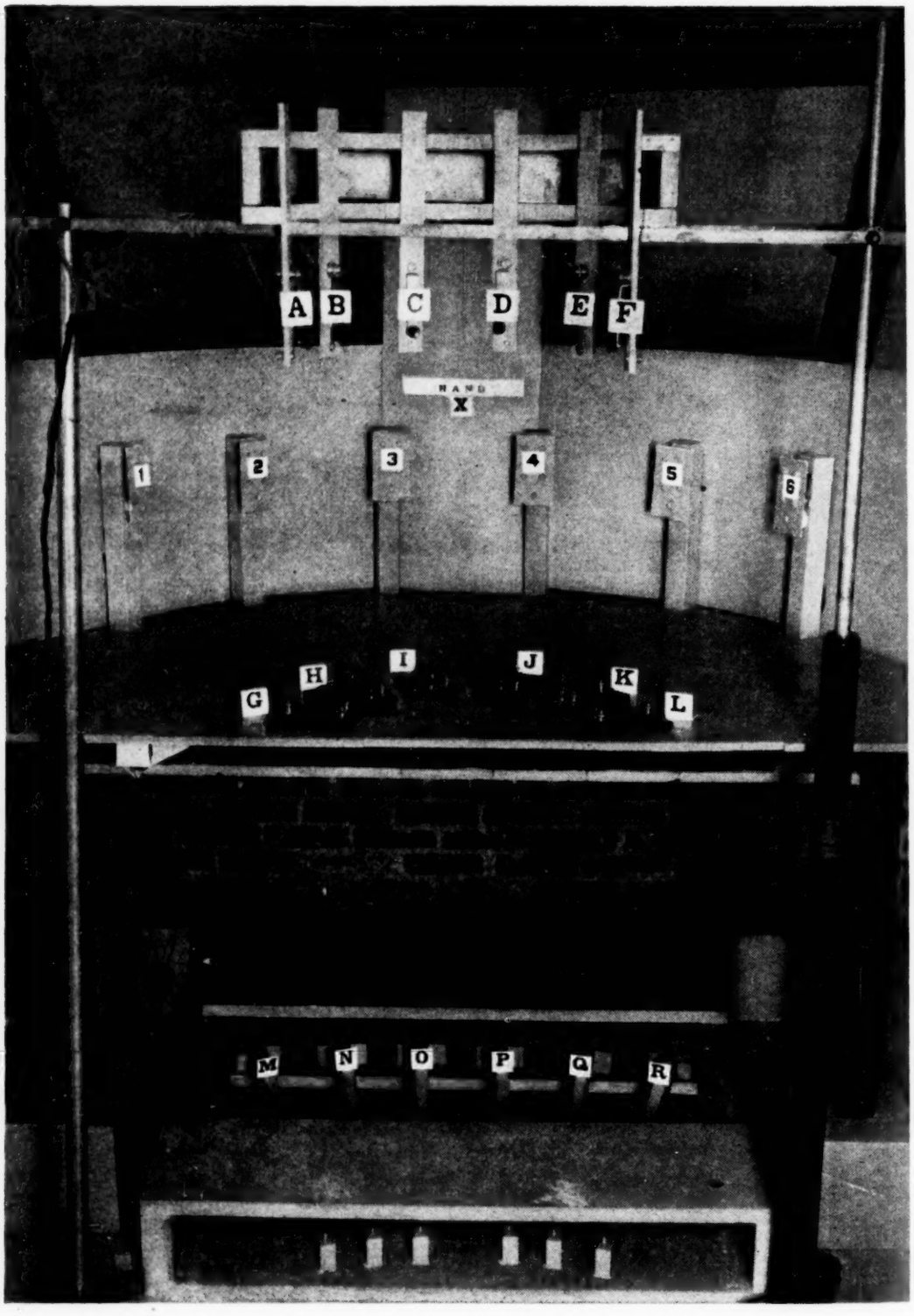

PLATE I. The subject's apparatus. This apparatus is designed to present a sequence of six flashes of light at the positions indicated by numbers 1, 2, 3, 4, 5, 6. The pattern presented can be signaled back by the subject through head keys (*A*, *B*, *C*, *D*, *E*, *F*) or through hand keys (*G*, *H*, *I*, *J*, *K*, *L*) or through pedals (*M*, *N*, *O*, *P*, *Q*, *R*).

appears. By a similar device the experimenter can raise and lower a second card on which are the following words: HEAD, HAND, FOOT, HEAD–HAND, HEAD–FOOT, HAND–HEAD, HAND–FOOT, FOOT–HEAD, FOOT–HAND, HEAD–HAND–FOOT, HEAD–FOOT–HAND, HAND–HEAD–FOOT, HAND–FOOT–HEAD, FOOT–HEAD–HAND, FOOT–HAND–HEAD.

Prior to the presentation of a pattern the experimenter adjusts the rear card so that one of the above words is directly behind the rectangular window but not visible to the subject until, at the proper moment, the front screen is lowered.

Now we will consider the apparatus for presenting a pattern of light-flashes to the subject.

On the table, Plate I, are six posts numbered *1*, *2*, *3*, *4*, *5*, *6*. These posts are one meter distant from the center of the subject's head and separated by an angle of 16°. On each post is a miniature electric lamp. Successive flashing of these lamps presents a pattern to the subject as, for example, that represented by the sequence of lights: 6 2 5 4 1 3.

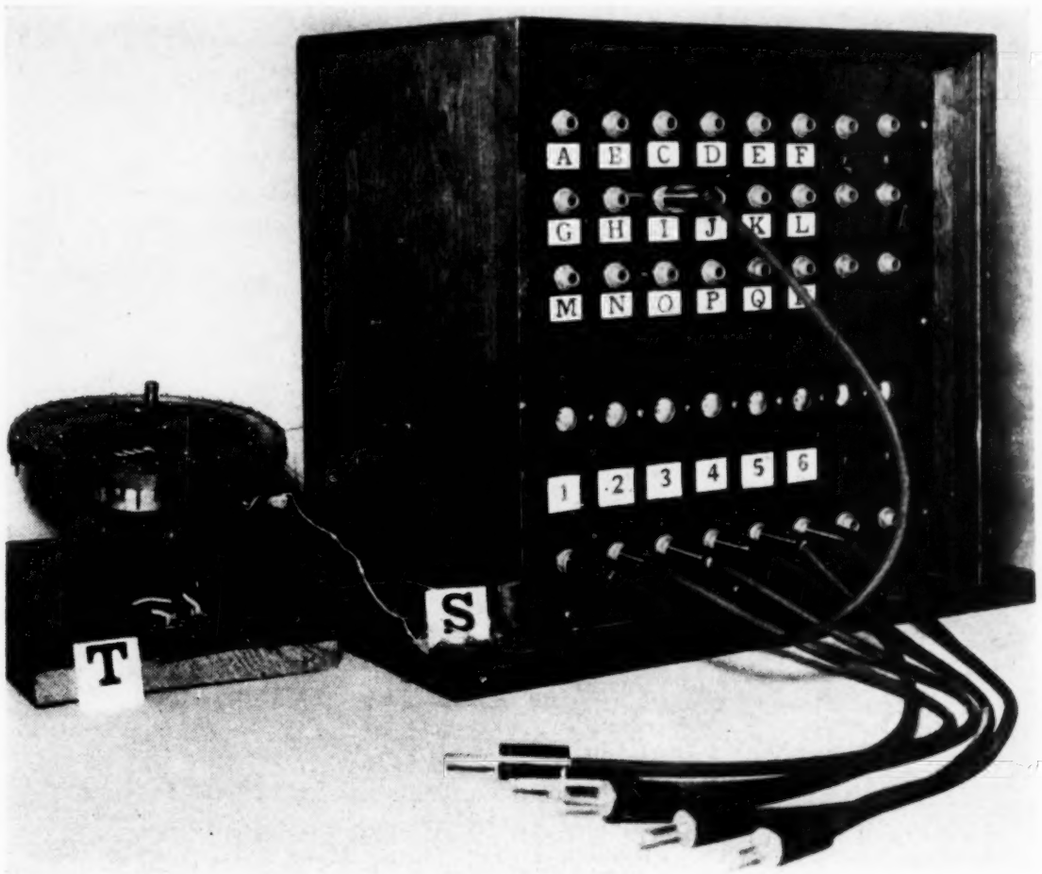

PLATE II. Control apparatus. This apparatus is used for two purposes. First, through it the experimenter controls the sequence and spatial pattern of lights presented to the subject. Second, signal lights on the control board itself (above 1, 2, 3, 4, 5, 6) indicate errors of the subject in reproducing a pattern. The timing clock (*T*) is shown at the left.

A wire from lamp No. *1* is connected to the *sleeve* contacts of the three jacks in the first vertical column of the control board (*A*, *G*, *M*) shown in Plate II. A wire from lamp No. *2* is connected to the *sleeve* contacts of the three jacks in the second vertical column (*B*, *H*, *N*). The wire from lamp No. *3* is connected to the *sleeve* contacts of the jacks (*C*, *I*, *O*) in the third vertical column, and so on.

All electrical impulses to the subject's lamps pass through the sleeve contacts of the telephone jacks.

The six plugs pictured at the bottom of the control board, Plate II, receive electrical impulses from the timing clock. The first impulse is received by plug No. *1*, the second impulse by plug No. *2*, the third by plug No. *3*, and so on. In the photograph the first plug is shown connected

with jack *I*; with this connection the first impulse from the timing clock is delivered through the sleeve contact to signal lamp No. *3* (Plate I). This same signal lamp would flash if the experimenter had inserted the plug into jack *C* or into *O* because, as noted above, the sleeves of jacks *C*, *I*, *O* are connected by a common wire to lamp No. *3*.

To plug in a pattern for a given test the experimenter notices the first light to be flashed. If, for example, that is No. *3*, the plug must be inserted in some jack in the third column. Next he notices the kind of key to be used by the subject in reproducing this light. If this is a head key, the plug is inserted in *C*; if a hand key, the plug is placed in *I*; if a pedal, in *O*. In a similar way he locates the jack for the second, third, and other lights in the pattern. With a little practice this is not so complicated as it seems.

The timing clock, *T*, in Plate II, is a telechron motor which rotates an arm and contact-wire around a series of copper sectors.[4] The sectors are cut so that each electrical contact has a duration of 0.7 second. There is first a contact (0.7 sec.) which sounds a buzzer as a warning signal. This is followed by a pause of 1.3 sec. after which there are six successive contacts (total duration 4.2 sec.) with no interval between them. The wires from the timer lead to the plugs at the bottom of the control panel in sequence: first, second, third, fourth, fifth, sixth.

The timer ran continuously throughout the experimental hour. Only when a master switch, *S* (Plate II), was thrown, did the pattern of light-flashes appear before the subject.

The electric current for the stimulus-lights as well as for the signals on the experimenter's panel was that from a six-volt rectifier connected to a 110-volt outlet, with resistance introduced to bring the voltage down to about 2.5 volts. The synchronous timing motor was run directly off the 110-volt, 60 cycle, current.

Procedure.—After a subject was comfortably seated and the head keys and pedals were adjusted, he was given the following typewritten instructions:

> This is a study of the ability to reproduce a pattern of lights. A pattern will be presented on the six posts at the back of the table. Within easy reach are six hand keys, six head keys, and six pedals by means of which you will reproduce the pattern presented. For each row of keys the key farthest to the left corresponds to the light farthest to the left; the next key to the next light, and so on; the key farthest to the right corresponds to the right-end light.
>
> Before the presentation of each pattern you will be instructed whether to respond with the FEET, HANDS, HEAD, or whether in a mixed mode such as HEAD–HAND–HEAD–HAND–HEAD–HAND, or HAND–HEAD–HAND–HEAD–HAND–HEAD, or HAND–HEAD–FOOT–HAND–HEAD–FOOT. The card at the rear of the table will indicate the manner of reproduction in a given trial.
>
> The three hand keys to the left should be pressed with the left hand and the three to the right with the right hand. Similarly, the three pedals to the left should be pressed with the left foot and the three to the right with the right foot.
>
> After a warning signal from a buzzer, the lights will be flashed. Look at the lights during the presentation and count aloud—one, two, three, four, five, six—as the lights flash.[5] Then reproduce the pattern with the keys as previously instructed.
>
> Do as well as you can and don't worry if you miss.

To make certain that the subject understood the instructions and could carry them out, a practice series of seven patterns was presented, using a different mode of reproduction on each trial. These practice trials were representative of the patterns and types of reproduction described below.

In an actual test the experimenter proceeded as follows. First he put the plugs into the jacks of the control panel so as to present the pattern called for on the data sheet and to test the ability

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[4] We found that this telechron motor sometimes did not maintain a constant speed in the horizontal position, and so we kept it tilted at an angle. The motor was originally designed to operate an electric clock while mounted in a vertical position. A better construction would be to mount the telechron motor vertically and gear it to a perpendicular shaft.

[5] Previous experience has shown that if the subjects are left to their own devices, some of them assign numbers or letters to the stimulus-positions and retain a pattern through a verbal surrogate. Counting eliminates the naming reaction and the likelihood of purely verbal retention. Compton also instructed his subjects to count.

of the subject to reproduce this pattern in a specified mode of reproduction. Next he adjusted the setting for the card instructing the subject to reproduce the pattern in a given mode, *e.g.*, HAND or HEAD–FOOT. This card was not exposed to the subject, however, until about one second before the warning buzzer sounded, and it was left in view until the subject had responded. The master key which sounded the warning signal and presented the light flashes was closed at a convenient time and opened immediately after the presentation.

The subject's response was recorded on special data sheets. The record showed the order in which the keys had been pressed by the subject, indicating the correct responses and errors.

Plan of the Series.—Seven modes of reproduction were used in the experiment. Three were single modes (HAND, HEAD, FOOT), three double modes (HEAD–HAND, HEAD–FOOT, HAND–FOOT), and one was triple (HAND–HEAD–FOOT). These modes were employed with

TABLE I

THE MODES OF REPRODUCTION

Complexity	Order						Symbol
	1	2	3	4	5	6	
Single modes	Ha	Ha	Ha	Ha	Ha	Ha	(Ha)
	He	He	He	He	He	He	(He)
	F	F	F	F	F	F	(F)
Double modes	He	Ha	He	Ha	He	Ha	(He-Ha)
	Ha	He	Ha	He	Ha	He	
	He	F	He	F	He	F	(He-F)
	F	He	F	He	F	He	
	Ha	F	Ha	F	Ha	F	(Ha-F)
	F	Ha	F	Ha	F	Ha	
Triple modes	Ha	He	F	Ha	He	F	(Ha-He-F)
	Ha	F	He	Ha	F	He	
	He	Ha	F	He	Ha	F	
	He	F	Ha	He	F	Ha	
	F	He	Ha	F	He	Ha	
	F	Ha	He	F	Ha	He	

equal frequency throughout the experiment. The total series was planned so that each of the modes would be used once in every seven trials; within a group of seven trials, however, the order was haphazard so the subject had no basis for anticipating which mode of reproduction would next be employed.

Every double mode has two forms. For example, if the head and the hand are to be used alternately in reproducing a pattern, the subject can start with the head (HEAD–HAND–HEAD–HAND–HEAD–HAND) or he can start with the hand (HAND–HEAD–HAND–HEAD–HAND–HEAD). Similarly, there are six variations in form of the triple mode as indicated in Table I. These different forms of a mode were used with equal frequency throughout the experiment; for double modes the two forms were alternated and for the triple, the six forms

were used in rotation. This was done to distribute practice among the different forms of a mode of reproduction.[6]

Table I shows three levels of complexity in the subject's mode-set: single, double and triple modes. The table also gives the sequences of muscle groups employed in reproducing the patterns, and a symbol for the seven modes (to be used in the tables of this paper).

The patterns are recorded in Table II. In selecting these patterns we saw to it that light

TABLE II

THE PATTERNS

Pattern Number	Pattern	Pattern Number	Pattern	Pattern Number	Pattern
1	5 6 3 2 1 4	11	1 3 2 5 4 6	21	2 3 1 5 4 6
2	4 6 3 2 5 1	12	1 2 5 4 6 3	22	5 1 6 4 3 2
3	1 6 4 3 2 5	13	2 6 3 1 5 4	23	3 6 1 2 5 4
4	6 5 1 4 3 2	14	6 1 3 2 5 4	24	1 6 3 2 5 4
5	1 5 6 4 3 2	15	4 6 1 3 2 5	25	6 1 4 3 2 5
6	5 2 1 4 6 3	16	2 1 5 4 6 3	26	3 6 4 1 2 5
7	3 6 1 2 5 4	17	4 5 6 1 3 2	27	6 3 2 5 4 1
8	4 3 2 5 1 6	18	2 6 4 3 1 5	28	4 2 5 1 6 3
9	3 1 2 5 4 6	19	5 6 4 3 2 1	29	2 5 6 4 3 1
10	5 3 6 4 1 2	20	3 2 5 4 6 1	30	6 2 5 4 1 3

No. *1* (see Plate I) flashed first in five of the patterns, second in five, third in five, and so on; similarly, that light No. *2* flashed five times in each of the serial positions; and the same was arranged for lights *3*, *4*, *5*, *6*.

The patterns were chosen on the basis of preliminary study to give a wide range of difficulty. They were then arranged in a chance order and given numbers from one to thirty as shown in Table II.

During the first, third, fifth and seventh experimental hours the patterns were presented in the order given in Table II. To equalize practice this order was reversed on the second, fourth and sixth experimental periods.

The experiment consisted of seven series of thirty trials, a grand total of 210 trials per subject. In the entire experiment each pattern was presented seven times—once with each of the seven modes of reproduction. Although the patterns were repeated and the modes of reproduction were repeated, no particular combination of pattern and mode occurred twice in the experiment. Every task, in a sense, was unique.

Practice periods were equally spaced. The subjects came three times a week to the laboratory.

Data Sheets and Reproduction Scores.—Seven forms of mimeographed data sheet were prepared for the main experiment. At the top of each sheet was a line for name of the subject and date. In a column at the left were the patterns to be presented on the day (see Table II). In the next column were the modes of reproduction trial by trial, *e.g.*, Ha or F-Ha (see Table I).

A column of cross-ruled lines was provided to record responses of the subject. If the subject reproduced the pattern correctly in the required mode, the lamps on the control panel flashed in order: one, two, three, four, five, six. Omissions, reversals, incomplete patterns were recorded. Finally, the data sheet provided spaces for recording comments made by the subject or by the experimenter during each trial.

At the close of the experiment the data sheets were sorted and scored. It was decided to ignore errors and to score each trial simply as right or wrong. The reason for this decision is a certain ambiguity of interpretation when a light on the control board failed to flash. Such failure might be due either to: (*a*) the fact that the subject forgot before he could reproduce the pattern; or, (*b*) the fact that he used the wrong kind of key, *e.g.*, pedal instead of head key, when the space-

[6] We arbitrarily assumed that the variant forms are equal in difficulty. We might equally well assume that there are fifteen modes instead of seven (see Table I). From this latter standpoint each of the 'six' triple modes received only one-sixth the amount of practice of the single modes. This point should be kept in mind when considering the results.

time pattern was correctly apprehended (error in the mode of reproduction rather than in the pattern-set).

In scoring the data sheets each trial was marked as right or wrong; no partial score was given for trials which contained errors of any kind. Throughout the following presentation of results the raw score is simply the number of patterns correctly reproduced by a subject on a given day, or for a given mode of response.

Subjects.—Twenty-two subjects were employed in the experiment, nine women and thirteen men. Since no sex differences were found, these twenty-two subjects will be regarded as a single group. The subjects were sophomores, juniors and seniors in psychology classes at the University of Illinois.

Results

Reliability.—Reliability of the test was studied by correlating scores for odd-numbered trials with scores for even-numbered trials. This was done for each mode and also for the total scores regardless of mode (all odds against all evens).

Since the split-half method gives coefficients of reliability for a short series, we used the Spearman-Brown "prophecy formula" for determining the reliability of a series of full length. The coefficients obtained in this way are presented in Table III.

TABLE III

Coefficients of Reliability

Mode	r	P.E.$_r$
Ha	.91	.02
F	.91	.02
He	.91	.03
Ha-F	.91	.03
He-F	.85	.04
He-Ha	.91	.03
He-Ha-F	.89	.03
Total	.96	.02

Values are consistently high and probable errors low, which indicates that a random selection of 30 patterns would, with high probability, give the same result as another random selection of 30 patterns, under conditions of the experiment.

Relative Difficulty of the Modes of Reproduction.—Table IV shows for all subjects the number of correct responses classified according to the mode of reproduction. For example, subject *I* while using the hand keys reproduced correctly 23 out of the 30 patterns; while using the foot keys he reproduced 21 patterns correctly out of 30, and so on. In this table the subjects are ranked from the one with the highest to the one with the lowest total score.

At the bottom of the table is given the total score for the group of 22 subjects distributed by mode of reproduction. On the basis of these totals it is clear that reproduction of patterns with the hand

TABLE IV

NUMBER OF CORRECT REPRODUCTIONS OF THE SUBJECTS DISTRIBUTED ACCORDING TO MODE

Subject	Single			Double			Triple	Totals
	Ha	F	He	Ha-F	He-F	He-Ha	He-Ha-F	
I	23	21	24	15	10	16	8	117
E	25	22	20	17	11	12	7	114
K	22	23	21	15	12	10	9	112
J	19	21	14	11	8	14	7	94
Q	17	17	14	14	12	10	10	94
S	15	20	12	12	11	11	11	92
R	22	15	17	8	12	6	10	90
B	22	18	16	12	8	5	4	85
U	19	19	14	9	5	7	8	81
D	15	13	13	9	11	8	7	76
P	19	11	12	7	6	9	11	75
O	15	15	12	10	9	7	7	75
H	13	17	14	7	8	7	5	71
N	11	9	11	8	10	9	6	64
V	13	16	13	5	8	4	4	63
M	10	11	7	12	11	5	5	61
A	15	13	6	9	4	10	4	61
G	16	16	10	9	3	5	0	59
F	13	12	7	8	5	4	3	52
L	7	13	5	4	3	2	2	36
T	5	5	5	4	4	1	5	29
C	6	2	4	0	3	3	1	19
Total	342	329	271	205	174	165	134	1620
Mean	15.5	14.9	12.3	9.3	7.9	7.5	6.1	73.6
S.D.	5.5	5.3	5.2	4.0	3.2	2.0	3.1	

keys results in higher scores than reproduction with other keys singly or in combination. The foot keys bring slightly lower scores than the hand keys, and the head keys still lower.

In explanation of this order for the single modes (HAND, FOOT, HEAD) it is suggested that habituation may play some part. Hand keys and pedals are familiar to all subjects but the head keys are unusual and unfamiliar. To press a head key the subject is required to make an unusual coördination of muscles in the neck and upper trunk in order to move forehead or temple to a particular key.

The totals in Table IV show that the scores for the double modes of reproduction are consistently lower than those for the single modes. The probable explanation of this lies in the relative complexity of the task for single and double modes. In the double modes a subject is required to respond alternately, for example, with the hand and foot; at the same time he must establish and retain a *pattern-set*. Alternation between two motor systems is a more complex performance than using only one. The subject is forced to attend to the instructions for a particular mode of reproduction, either before the pattern has flashed or during reproduction or both.

Even though a subject apprehends the space-time pattern correctly, he may make an error by using the wrong motor system thus making the entire response count as an error.

Scores for the triple mode are definitely the lowest of all. In the triple mode the subject is required to use three motor systems in sequence. He must hold this sequence in mind (or possibly read it from the visible card), as: HEAD–HAND–FOOT or HAND–HEAD–FOOT. If he correctly apprehends the space-time pattern, he may still make an error by pressing the wrong kind of key. Moreover, there are six forms of the triple mode and only two of a double mode. The subjects, therefore, had less opportunity to become habituated to a particular form of the triple mode than to a form of a double mode.

The total scores in Table IV reveal three levels of complexity: single modes, double modes, the triple mode.

TABLE V

NUMBER OF CORRECT REPRODUCTIONS ON SUCCESSIVE PRACTICE PERIODS DISTRIBUTED ACCORDING TO MODE

Mode	Experimental Period							Totals
	I	II	III	IV	V	VI	VII	
Ha	20	37	42	51	60	63	69	342
F	33	29	45	53	57	59	53	329
He	11	25	36	39	48	50	62	271
Ha-F	16	23	31	34	30	49	22	205
He-F	13	19	27	28	19	22	46	174
He-Ha	10	17	18	15	34	36	35	165
He-Ha-F	6	7	18	17	21	24	41	134
Total	109	157	217	237	269	303	328	1620
Mean	15.6	22.4	31.0	33.9	38.4	43.3	46.9	
S.D.	8.2	8.8	10.0	14.0	15.5	13.0	13.4	

The Effect of Practice.—Table V presents the total number of correct reproductions for the group distributed according to practice period and to mode. This table can be interpreted only in relation to Table VI, which records the number of times each mode was called for during the successive practice periods.

In explanation of Table VI it may be said that the seven modes of reproduction were employed with unequal frequency on a given day. This unequal frequency is a mathematical necessity when 30 trials per day are used, because 30 is not a multiple of 7.

Obviously the total number of correct responses shown in Table V must be viewed in relation to the total possible number of correct responses. The maximal number of correct responses can be obtained

by multiplying the figures in Table VI by 22, the number of subjects. To illustrate, from Table VI we learn that reproduction by the HAND keys was called for 5 times on the first practice period; since there were 22 subjects, the maximal number of correct responses would be 110. On the second day reproduction by HAND keys was called for 3 times; the maximal number of correct responses on this day would be 66.

To study the effect of practice we have taken three steps. First, we added together the scores for the three single modes (Ha, F, He) which are shown in Table V; and similarly we added together the scores for the three double modes (Ha-F, He-F, He-Ha). This grouping reduced the tabulation to three levels of complexity. Second, with the information contained in Table VI these scores were converted into percentages. Each percentage shows what

TABLE VI

NUMBER OF TIMES EACH MODE WAS CALLED FOR DURING THE SUCCESSIVE PRACTICE PERIODS

Mode	Practice Periods							Totals
	I	II	III	IV	V	VI	VII	
Ha	5	3	5	4	5	4	4	30
F	5	3	5	4	4	5	4	30
He	4	5	4	4	5	3	5	30
Ha-F	4	5	4	5	3	5	4	30
He-F	4	5	3	5	4	4	5	30
He-Ha	4	5	4	4	4	5	4	30
He-Ha-F	4	4	5	4	5	4	4	30
Total	30	30	30	30	30	30	30	210

proportion of the maximal number of responses was correctly reproduced on a given day by the group of subjects. As a final step the percentage scores were plotted in the form of learning curves.

Figure I reveals a distinct practice effect for single, double, and triple modes of reproduction. The curve for single modes is consistently the highest from first to last. The curve for the triple mode is the lowest except on the last day. This sudden rise might be due to the chance selection of patterns.

It will be noted presently (Table VII) that the patterns vary widely in difficulty; and on this day only four triple patterns were used (Table VI). With a small number of patterns and a wide range of pattern-difficulty, the chance selection of patterns can make a considerable difference in the reproduction scores. This factor of pattern selection might explain other irregularities in the curves of Fig. I.

Practice results in increased scores for all modes. The limit of practice appears to be higher with the single than with the double and triple modes of reproduction. This difference in the limit of practice is understandable in view of the differences in complexity of the *mode-set* for single, double, and triple modes. Each curve approaches a limit for its own level of complexity.

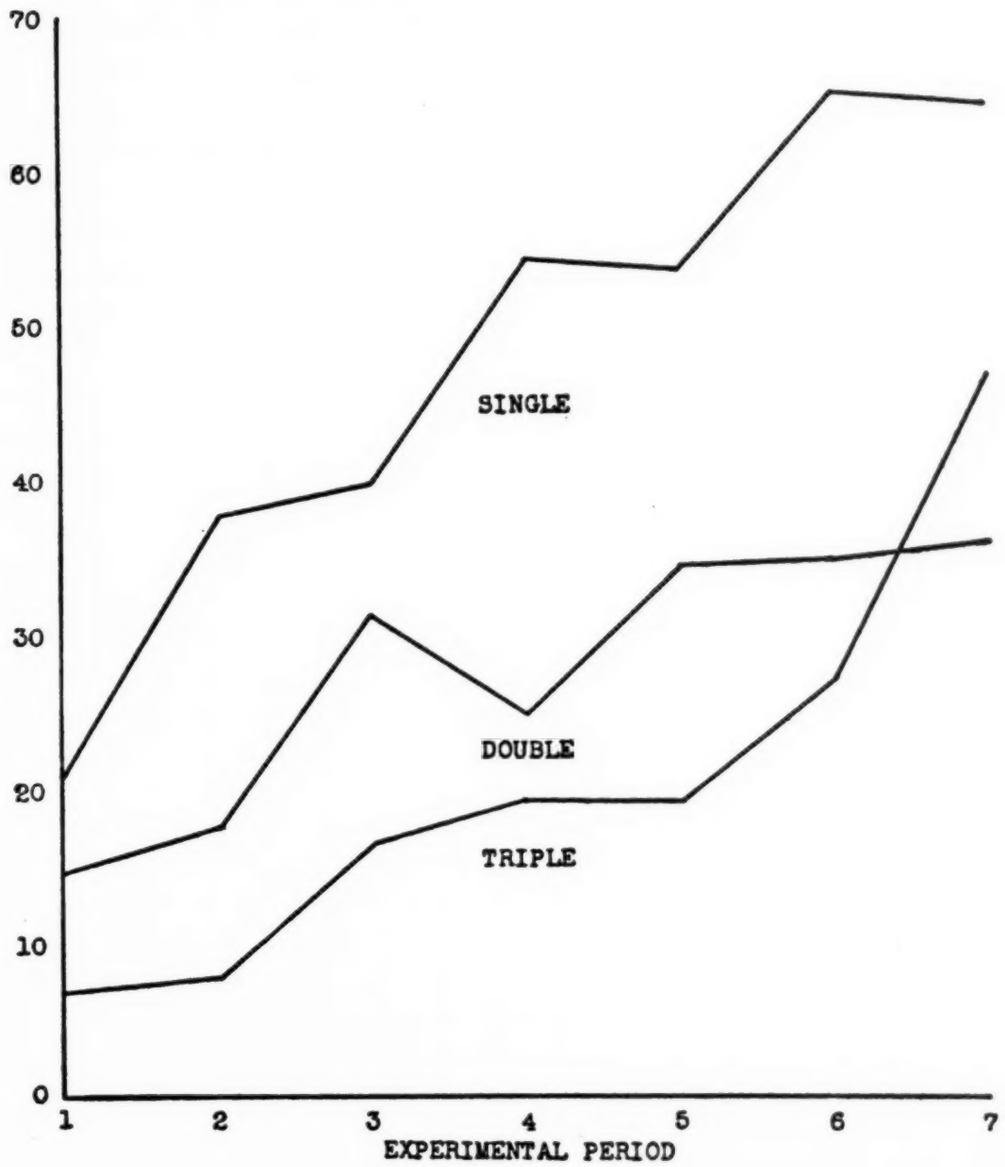

FIG. 1. Effect of practice upon the single, double and triple modes of reproduction. Along the base line are plotted the seven successive experimental periods. The vertical shows percentage of the maximal score which was actually obtained on a given day by the total group of subjects.

The curves, in general, tend to spread apart with continued practice rather than to converge. This is indicated in Table V by the gradual increase in the standard deviations as practice continues.

Pattern Difficulty.—Compton found that if a pattern was difficult

when presented to the eye, it was difficult also when presented to the ear or to the skin. In one of his tests the patterns were arranged in order of difficulty when presented visually and again when presented tactually. The two rank orders were similar, the coefficient of correlation (*rho*) being 0.96. Compton concluded that the difficulty of reproducing a pattern is largely a matter of organizing the spatial and temporal relations within the point-stimulations.

In contrast with Compton's work the present experiment utilized a single mode of presentation but seven modes of reproduction. How far under present conditions does difficulty of the task depend upon the space-time relations within the patterns flashed to the subject?

The thirty patterns have been ranked in order on the basis of total scores from the highest to the lowest. The patterns are designated by number in Table VII. Reproduction scores in the seven modes are shown for each pattern.

TABLE VII

RELATIVE DIFFICULTY OF THE PATTERNS

Pattern Number	Modes							Totals
	Ha	F	He	Ha-F	He-F	He-Ha	He-Ha-F	
5	19	12	19	17	15	15	12	109
19	19	18	17	13	9	9	10	95
17	19	16	17	13	8	10	9	92
22	19	18	15	6	12	10	10	90
8	18	15	13	9	10	12	7	84
29	18	12	13	10	12	8	8	81
21	16	17	12	6	11	8	6	76
11	14	17	13	9	3	8	3	67
1	2	19	16	9	8	4	5	63
3	18	17	0	9	4	8	7	63
20	12	14	11	8	5	6	6	62
4	16	16	2	8	7	2	7	58
7	13	12	11	9	0	6	5	56
15	14	12	10	6	6	5	3	56
9	13	12	4	9	6	4	5	53
23	10	12	11	6	5	5	3	52
24	11	10	10	5	6	6	3	51
25	11	6	11	7	5	5	5	50
10	11	9	10	6	1	4	3	44
13	8	7	8	7	6	6	2	44
27	9	8	6	8	6	4	3	44
26	8	7	3	6	8	4	3	39
16	7	6	5	5	3	4	2	32
28	8	6	4	3	4	2	2	29
2	9	6	5	0	3	3	2	28
18	5	7	7	3	2	3	1	28
14	8	6	6	1	2	0	2	25
30	3	6	4	2	4	3	0	22
12	0	4	5	3	2	0	0	14
6	4	2	3	2	1	1	0	13
Total	342	329	271	205	174	165	134	1620

In making an analysis of pattern-difficulty we have grouped together the single modes and ranked the patterns on the basis of total scores for these modes. Similarly, we grouped the double modes, added their scores and ranked the patterns. Finally, the scores for the triple mode were arranged in a rank order. Coefficients of correlation were then computed with this result:

Single and double modes, *Rho* = 0.85
Single and triple modes, *Rho* = 0.89
Double and triple modes, *Rho* = 0.87

These values are positive and consistently high. They indicate that if a pattern is difficult when reproduced in one mode, it is difficult when reproduced in another.

One way to discover factors in pattern-difficulty is to compare the easy and the difficult patterns, making diagrams on a six-point plan of the apparatus.[7] We have made such a study and find that easy patterns in contrast with difficult ones have certain characteristics. In easy patterns there are regular sequences of points which are near together in space. Further, in easy patterns relatively few reversals of eye movement and of bodily adjustment are required in the pursuit of a successively flashing light. Also in easy patterns the geometrical figures are relatively open, free from crossing lines, while in difficult patterns there are more criss-crossing lines in the geometrical pattern.

Our analysis of pattern-difficulty confirms that of Compton, who listed the following six factors in pattern-difficulty:

1. The simplicity of the spatial pattern or design.
2. Proximity of successive point-stimulations.
3. Direction of bodily movement made in adjusting to the point-stimulations, whether from left to right or reverse.
4. Number of reversals in ocular and gross pursuit movements.
5. Number of line crossings in the spatial geometrical pattern.
6. Position of a difficulty within the total point sequence, errors being more likely in the center of a sequence.

If we combine Compton's analysis of pattern-difficulty with the present one, we can say that difficulty lies in the integration of successive point-stimulations. To a considerable extent this difficulty is independent of the sensory channels through which the point-stimulations are given. It is also relatively independent of the motor channels through which the subject signals the pattern to the experimenter. Although reproduction scores do vary with sensory

[7] The information required for such an analysis is contained in Tables II and VII. The plan of the apparatus is shown in Plate I.

and motor factors as well as with the amount of practice, there is no doubt that these scores depend to a high degree upon central integrating processes.

Ability of the Subjects in Relation to Mode of Reproduction.—In Table IV the twenty-two subjects are ranked in order from the one with the highest score to the one with the lowest. Note the wide range of individual differences in performance from *I* with a reproduction score of 117 to *C* with a score of 19.

In Table VIII the subjects are again ranked in order of their

TABLE VIII

NUMBER OF CORRECT REPRODUCTIONS OF THE SUBJECTS ON SUCCESSIVE PRACTICE PERIODS

Subject	Experimental Period						
	I	II	III	IV	V	VI	VII
I	10	18	15	19	18	17	20
E	7	8	15	19	19	19	27
K	6	11	16	16	17	25	21
J	8	9	10	17	15	18	17
Q	7	7	7	12	21	21	19
S	6	9	15	10	15	20	17
R	10	12	8	13	15	15	17
B	5	8	13	14	16	15	14
U	5	6	10	12	16	14	18
D	3	6	12	10	12	18	15
P	2	8	12	12	14	12	15
O	7	10	12	10	9	13	14
H	4	7	10	8	13	13	16
N	3	6	5	14	10	13	13
V	4	4	9	8	11	12	15
M	2	5	8	10	9	9	18
A	4	3	12	11	10	10	11
G	4	6	9	8	11	11	10
F	5	8	5	6	7	12	9
L	3	2	8	4	4	5	10
T	4	2	5	3	4	7	4
C	0	2	1	1	3	4	8
Total	109	157	217	237	269	303	328
Mean	5.0	7.1	9.9	10.8	12.2	13.8	14.9
S.D.	2.5	3.6	4.3	4.7	4.9	5.1	4.9

total scores. Individual scores are shown for each of the seven experimental periods. The rows of figures reveal the extent to which each subject gained by practice.

Total scores for the group as a whole are given and also the mean number of correct reproductions per period. As we might expect, the mean score increases from day to day with practice. The standard deviation also increases, which indicates that practice *increases* the extent of individual differences.

In Table IV the reproduction scores of the subjects are distributed

according to mode. Inspection of Table IV raises a question whether the subject who makes a relatively high score while using one mode of reproduction is likely also to make a relatively high score while using another mode.

To study this matter coefficients of correlation were computed between scores in the different modes. Table IX presents the values

TABLE IX

COEFFICIENTS OF CORRELATION BETWEEN SCORES FOR THE DIFFERENT MODES OF REPRODUCTION

	Ha	F	He	Ha-F	He-F	He-Ha
F	.80					
He	.89	.80				
Ha-F	.76	.78	.69			
He-F	.51	.49	.67	.69		
He-Ha	.68	.65	.68	.74	.53	
He-Ha-F	.54	.45	.57	.50	.69	.60

of r between pairs of scores in different modes of reproduction. An examination of these figures shows that they are positive and significantly high. This indicates the presence of a common factor of ability to reproduce the patterns.

A factor analysis of this table of coefficients of correlation has been made by the Thurstone centroid method.[8] Three factors were extracted. The first of these factors is heavily weighted, being over eight times as important as the second factor and approximately nineteen times as important as the third factor.

The first factor is a general one common to all modes of reproduction and of utmost importance. The particular muscle system through which a pattern is reproduced is relatively unimportant as compared with this first common factor. The factor is assumed to be one of ability to integrate stimulus-points into a space-time pattern and to reproduce the integrated pattern immediately.

The second factor has positive loadings in the single modes of reproduction (HEAD, HAND, FOOT) and zero loadings in the other modes. Obviously this factor is one which varies with the simplicity or complexity of the task.

The third factor is relatively unimportant and we have been unable to attach any psychological significance to it.

Compton also found that subjects who made high scores when patterns were presented in one sensory mode tended to make high scores in other sensory modes. His coefficients ranged from 0.76 to 0.92. Apparently the ability to reproduce patterns is relatively independent of the sensory channel through which they are presented as well as of the motor channel through which they are expressed.

[8] Details of this factor analysis are recorded in Thomas' doctoral thesis; see footnote No. 3.

Discussion

Comparison of the Experiments of Compton and Thomas.—As we noted in the introductory section of this paper, Compton employed seven modes of pattern-presentation and a single mode of pattern-reproduction. Thomas, contrastingly, employed a single mode of presentation and seven modes of reproduction. Taken together these studies throw light upon the rôle of sensory and motor factors in organic set.

It is instructive to compare the percentages of correct responses in the two studies:

Compton		*Thomas*	
Mode of Presentation	Percentage Correct	Mode of Reproduction	Percentage Correct
Auditory	58	Hand	52
Visual	57	Foot	49
Visual-auditory	53	Head	41
Tactual	38	Hand-foot	31
Auditory-tactual	37	Head-foot	26
Visual-auditory-tactual	37	Head-hand	25
Visual-tactual	33	Head-hand-foot	20

Taken as a group the scores in Thomas' experiment are lower than those in Compton's. The difference probably indicates that the subject's task was more difficult (complex) in the experiment of Thomas than in that of Compton. A factor of difficulty in the present experiment which was absent in the former one is the necessity of attending to the motor system to be used in reproducing a pattern. In Compton's experiment errors in the mode of reproduction were non-existent as only one mode was employed.

A direct comparison can be made between Compton's *visual* mode of presentation (manual reproduction) and Thomas' *hand* mode of reproduction (visual presentation). For visual presentation the percentages of correct responses is 57; for hand reproduction the percentage of correct responses is 52. The two figures are so nearly alike that the present result may be regarded as a confirmation of the former.

The above figures demonstrate that the reproduction scores depend both upon the mode of presentation and upon the mode of reproduction. The more usual and familiar modes have the advantage. Also mixed modes, without sensory or motor, give lower scores than simple or non-mixed.

The correlation of test-scores in both experiments demonstrates clearly that when a subject is able to make a high score in one mode of presentation or in one mode of reproduction, he is able to make a relatively high score in other modes. This suggests that there is a common central factor of ability to integrate point-stimulations and

to reproduce the pattern immediately. Supporting this hypothesis is the fact that when a pattern is difficult in one sensory mode it tends to be difficult in all, and when it is difficult in one motor mode it tends to be difficult in the other modes.

Finally, in both experiments distinct practice effects were found in all modes. The limit of practice varied with the mode of presenting a task and with the mode of carrying it into action.[9]

Neural versus Neuromuscular Set.—Mowrer and others[10] have argued from experimental evidence that preparatory set has a central locus. Freeman,[11] however, has countered that: "Both central 'neural' conditions and peripheral 'muscular' conditions are involved in any set, and if no apparent muscular reactions are found to accompany a set, this no more proves that the locus of set is exclusively central than does the presence of such motor reactions prove that its locus is exclusively peripheral."

The argument is elusive. Psychologists agree that overt neuromuscular set exists. Sometimes an overt set is called a posture, sometimes a neuromuscular adjustment, sometimes a bodily set of attention; but apart from terminology there is no disagreement concerning the existence of the phenomenon itself. The argument centers upon the nature of neural or central set.

Evidence for the existence of a purely neural set is found abundantly in daily life. For example, I have resolved to take a trip; when the day comes I pack a suit-case, go to the station, buy a ticket, and get on the train. In the meantime, while *set* for this trip, I have several times relaxed in deep sleep, have been temporarily anesthetized, have exercised and relaxed perhaps every skeletal muscle in the body. The smooth muscles of blood vessels and alimentary tract also have repeatedly changed their tonus. During the week through which the set persisted I have walked into the country, attended a movie, and been in countless other environmental situations. Yet despite all of these sensory and motor changes the

[9] Compton found that practice *decreased* the differences among scores in his seven modes of presentation; practice curves approached a common level. Thomas found that practice *increased* the differences among scores in his seven modes of presentation, and *increased* individual differences; practice curves tended to spread apart. Before this result can be stated as a conclusion, however, it needs to be checked in a further experiment in which the distribution of pattern-difficulty and of practice on the patterns is more adequately controlled.

[10] Mowrer, O. H., Rayman, N. N., and Bliss, E. L., Preparatory set (expectancy)—an experimental demonstration of its 'central' locus, *J. exp. Psychol.*, 1940, **26**, 357–372; Mowrer, O. H., Preparatory set (expectancy)—further evidence of its 'central' locus, *J. exp. Psychol.*, 1941, **28**, 116–133. A study with a wholly different approach which favors a peripheral theory is: Knott, J. R., Some effects of 'mental set' on the electrophysiological processes of the human cerebral cortex, *J. exp. Psychol.*, 1939, **24**, 384–405.

[11] Freeman, G. L., 'Central' vs. 'peripheral' locus of set; a critique of the Mowrer, Rayman, and Bliss 'demonstration,' *J. exp. Psychol.*, 1940, **26**, 622–628.

determination to take a trip persisted and revealed itself in overt action.

Did this set reside for a week in some peripheral process? If one answers *yes*, it must be admitted that the peripheral basis for the set is unobserved and unknown. If the answer is *no*, it must be granted that the existence of neural set is purely speculative.

One reason why the argument is elusive is that *set* is not ordinarily described in neural terms. In daily life a set is described by reference to the world of objects and events in which the individual lives. Spatial relations and temporal sequences are noted by the individual, as well as the relative dominance of determinations, but what goes on in the brain is not known. When one speaks of a purely neural set, he has left psychological fact for speculative neurology.

What light, if any, do the experiments of Compton and Thomas throw upon this problem of the locus of set?

On the whole these experiments indicate that both central and peripheral factors are present in set. But a further experiment would be necessary to measure the relative importance of sensory, central, and motor processes in the set for immediate reproduction of patterns. Compton found that the sensory mode of presentation made a considerable difference in the reproduction score. Thomas found that the motor mode of reproduction was an important factor. These facts emphasize the importance of peripheral factors. On the other hand, both investigators found through correlational studies that the difficulty of a pattern depends upon space-time relations apart from sensory and motor factors, and that if a subject makes a high reproduction score in one peripheral mode, he is likely to make a high score in the other modes. These facts indicate the basic importance of central factors in organic set.

Summary and Conclusion

Patterns of light were presented to a subject by the successive flashing of miniature lamps. The subjects were instructed to reproduce the patterns by pressing keys immediately after the last light flashed. Signal keys operated by the head, the hands, the feet, were used both singly and in combination. A record was made of the subject's performance.

After the experiment each trial was scored as right or wrong. Analysis of the reproduction scores is the basis for the following conclusions:

1. Reliability of the test estimated by the split-half method varied with the mode of reproduction from 0.85 to 0.91. For the experiment as a whole reliability was 0.96.

2. When the test-scores were distributed according to the mode of reproduction an analysis revealed three levels of complexity, namely, those of: (*a*) the single modes in which only one kind of key was used; (*b*) double modes in which the subject alternated between two kinds of key; (*c*) the triple mode in which all three kinds of key were employed in rotation.

3. A study of practice curves indicated different limits of performance for single, double, and triple modes of reproduction respectively. The curves tended to spread apart with continued practice, approaching different limits of practice.

4. If a pattern is difficult when reproduced by one muscle group, it tends to be difficult when reproduced by other muscle groups. Coefficients of correlation for single, double, and triple modes were found to be 0.85, 0.87, 0.89.

5. Intercorrelations among the test-scores for the seven modes of reproduction ranged from 0.45 to 0.89. Factor analysis revealed a common factor which is assumed to be an ability to integrate light-flashes into a pattern and to reproduce the same immediately. A second factor was found which indicates a difference in performance between single and other modes.

6. A comparison of results in the present experiment with those obtained earlier by Compton indicates that the reproduction score varies markedly both with the sensory mode of presenting a pattern and with the motor mode of reproducing it. In other words, peripheral factors play an important rôle in establishing an organic set and in acting immediately upon it. On the other hand, correlational studies of reproduction scores emphasize central factors. It must be concluded that the ability to assume a set and to act upon it is one which depends in an important way upon both peripheral (sensory, motor) and central factors.

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INTERFERENCE WITH RECALL OF ORIGINAL RESPONSES AFTER LEARNING NEW RESPONSES TO OLD STIMULI[1]

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INTRODUCTION

The theory that forgetting can be accounted for by new learning (associative inhibition) is widely endorsed. Guthrie (**4**, p. 49) states the theory and indicates one of its difficulties: "If the laboratory experiment consists in establishing an association between the two members of a pair of syllables, so that the sight of the first syllable will recall the second because the second had regularly appeared after the first, a loss or a forgetting of this association is probably the effect of some new association acquired by the first word. But this is extremely difficult to prove, because the record shows only whether or not the second word was given in response to the first. If it fails to be given, it is hard to identify the response which presumably took its place."

Hilgard and Marquis (**5**, p. 117) make essentially the same point in discussing the interference theory of extinction: "The interference interpretation of extinction, if it is not to imply adaptation or other weakening independent of interference, must discover a source for strengthening those responses which are antagonistic to the conditioned response."

The quotations just cited indicate that a major problem in connection with the theory resides in the difficulty of identifying the new associations which presumably have so grown in strength that they are given in response to the old stimuli. Observations on this specific point are rare in the literature of this subject. Wendt (**10**) reports that monkeys, in an extinction situation, would jump about their cages, bite knobs on drawers, and in general would extinguish a conditioned habit by forming a new one. The present study of retention of verbal material attempts to identify and specify the new responses by forcing subjects to learn new responses to old stimuli; in this way the new response will be experimentally determined and not left to chance associations.

[1] The writer is indebted to Miss Dorothy M. Koch for assistance in conducting the experiments.

The voluminous literature on retroactive inhibition contains many references to which the present study is more or less directly related. It is generally agreed that the degree of similarity of interpolated learning is of primary importance in establishing inhibition of recall. For the most part, investigators have been content to study similarity in terms of form (9) or meaning (7) and have avoided direct interference by forcing new associations to be made to old stimuli in the interpolated learning period. The study by McGeoch and McGeoch (7) of the effect of interpolation of synonymous adjectives revealed that inhibition was greatest when the first adjective of a pair (the stimulus adjective) in the interpolated learning was synonymous with the first adjective of the original pair of associates. The recent work of Gibson (3) on generalization of inhibition is perhaps the most closely parallel to the present work, both in procedure and in the nature of the results, and the present work can be considered a modification and perhaps a substantiation, in part, of her work.[2]

Two experiments, one an individual and the other a group study, will be reported. In the first study individual subjects, each serving as his own control, learned two series of responses, one containing confusing or interfering materials, the other free from deliberate blocking elements. In the second experiment, two groups of subjects are compared for retention of original learning of the same material after subsequently differing experiences. The procedures and results of the two experiments will be described separately.

Experiment I.—The interference with recall of old responses following the learning of new responses to the original stimuli.

Procedure.—The general plan of this experiment was to have subjects learn a response R_1 to a stimulus S_1, then learn another response R_2 to the same stimulus, then a third response R_3 and finally a fourth response R_4 to the same stimulus. After learning three new responses to S_1 the subjects were tested for recall of R_1. Actually the subjects learned four lists of nonsense syllables, presented as paired associates, five pairs to a set. The first syllables in each set were the same in all four sets and served as S_1. The second syllables varied with each set and served as responses 1, 2, 3, and 4. As a control, each subject learned an equal number of sets of paired associates in which both stimulus and response syllables were different in each set. The syllables used are reproduced in Table I.

The pairs of syllables were drawn in India ink on glass slides (2″ × 2″) and projected on a screen by a Kodascope No. 1 Projector. To prevent serial learning of the responses and to insure the learning of the pairs as associates, the order of presentation of the pairs was systematically varied so that no two slides were ever shown in the same sequence. The use of slides has two further advantages over the use of a memory drum: (*a*) Each member of a pair of associates can be presented individually, thus obviating the necessity for duplicating materials and other additional preparations for scoring purposes. In the present experiment the first half of each slide was exposed for three seconds and then the second or response half of the slide was shown for an additional three seconds. In order to control the time of exposure, four thin rods were mounted

[2] Gibson used paired associates consisting of a drawn form and a nonsense syllable; the present experiment used only nonsense syllables and dealt with only a part of the problem she studied. The relation between the present study and that of Gibson will be discussed more fully later.

at equal distances on the rim of a kymograph placed just below the projection lens. The kymograph made one revolution in twelve seconds. The rods intercepted the beam of light from the projector every three seconds and appeared as shadows on the screen. The subject was instructed to make the response audibly either by anticipating the syllable or by pronouncing it after it was shown. Whenever a slide was shown for the first time, the whole slide would be exposed for six seconds during which the subject pronounced the second syllable aloud. (*b*) By using slides it is possible to control the learning of each pair of associates to some specified criterion by removing the slides as the criterion is met. In preliminary experiments in which all slides were retained until the whole list was learned it was found that some pairs were learned very quickly and received up to 15 or 20 overlearning trials while the subjects were struggling to fix one or two pairs that for some individual reason eluded them. In later recall sessions, these over-learned responses were, of course, remembered, and depending on their proportion in the series, confused the meaning of the results. In the present experiment slides were withdrawn from the series as soon as they had been anticipated correctly twice in succession.

TABLE I

SYLLABLES USED IN 'EXPERIMENTAL' SESSIONS

Set I	Set II	Set III	Set IV	Set V (Recall) Same as Set I
biv-lar	biv-dep	biv-kel	biv-gef	
dac-ris	dac-geb	dac-juc	dac-fof	
sab-mef	sab-lek	sab-pem	sab-yod	
dit-yek	dit-fuv	dit-caz	dit-mel	
fip-kas	fip-zut	fip-sar	fip-rux	

SYLLABLES USED IN 'CONTROL' SESSIONS

Set I	Set II	Set III	Set IV	Set V (Recall) Same as Set I
mof-dur	baf-zen	heg-saf	nus-wek	
ner-wib	sur-jum	tas-zon	zit-yev	
rix-tav	pof-hig	dev-pab	fim-nar	
kem-fap	res-jep	wum-fef	sul-kac	
fub-seg	gax-yib	lut-vep	yov-mip	

Two learning sessions, lasting about 45 minutes each, took place at an interval of one week, to the hour. In the 'experimental' sessions the subjects first learned one set of responses to the stimulus syllables; after a two-minute rest, they learned the next set, and so on for four sets. After the four sets were learned the experimenter announced: "I shall now show you the first halves of the first set of syllables you learned this afternoon. See if you can remember any of them. If you cannot, I will show you the second halves and we will continue until you have relearned all of them." No indication was given to the subjects that the different sets all had identical stimulus syllables. A record was kept of the number of exposures necessary to anticipate each slide correctly twice. The total number of exposures for any set served as a measure of learning for that set. In the control sessions the same procedure was followed in detail. The only difference between the two sessions consisted in the fact that the control slides were made up of independent sets with no prearranged possibilities of interference.

Subjects.—Twenty college students in psychology served as subjects. They knew nothing of the purpose of the experiment. Half of the subjects started with the experimental slides and the others started with the control slides. In order to eliminate any disturbing factors arising from possible differences in difficulty from one set of syllables to another, the subjects learned the four sets in a counter-balanced order, so that each set appeared in a different numerical position for four groups of five subjects. It should be noted that in experiments like the present,

counter-balanced orders do not necessarily eliminate the possible differing effects of individual sets; a set that may be difficult to learn as a beginning set may be easy to learn as a last set.

Results

Since the value of the results depends largely on the equal difficulty of control and experimental materials, attention is called to the relatively equal means for both sets (Columns A and E) in Table II. In general, the learning of successive sets becomes more difficult for the experimental syllables and easier for the control syllables. None of the differences between the groups is statistically significant.

The main point of interest is that the subjects required 90 percent of the trials taken to learn the original set in order to relearn that same set after experience with the interpolated sets. Eight of the twenty subjects required 100 percent or more trials to relearn the original set. Only 77 percent as many trials were needed to relearn the first set in the control series. Because of the small number of cases it was desirable to apply Fisher's (**2**, p. 127) method for determining the reliability of the difference in small samples. According to this treatment, the differences in percentages under the two conditions are reliable (between 1.5 and 1 chance in 100 of getting a difference in the same direction by chance alone).

Although the control syllables were learned in an increasingly efficient manner, there can be no question but that some retroactive inhibition was present simply from the learning of additional nonsense materials arranged in the same forms. Such interference has been demonstrated often (**9**), but is overshadowed in the present experiment by a general practice effect. The subjects gave ample evidence of such interference from previous learning in their faulty anticipations and in their repetitions of responses learned to some previous list. Gibson noted the occurrence of 'intrusion' and 'reversion' errors in both interpolated and recall learning. In the present experiment every subject made at least one such overt error. Syllables from the first and second sets would be pronounced as responses for stimuli in the third and fourth sets. In some cases these errors would persist to the point of embarrassment for the subject. Most subjects established discrimination quite readily and remained silent rather than risk a faulty response. Because this attitude was general, it was impossible to record the actual occasions on which intrusion or reversion responses were made implicitly. Not only were there intrusions and reversions from list to list but such errors occurred even within each list alone, sometimes repeatedly and overtly; occasionally the errors would take the form of compromises such as Gibson describes, but more often they would be direct errors. In most cases, subjects would take more time and trouble to unlearn

TABLE II

THE NUMBER OF SLIDE EXPOSURES NECESSARY TO LEARN EACH SET BY EACH SUBJECT UNDER CONDITIONS OF INTERFERENCE AND NO INTERFERENCE

Subject	Experimental (interference) Slide Sets						Control (no interference) Slide Sets						Diff. of Percent
	A	B	C	D	Relearn A	Percent of Original Trials to Relearn A	E	F	G	H	Relearn E	Percent of Original Trials to Relearn E	
1	39	43	35	28	29	.744	51	50	32	33	36	.706	.038
2	41	56	29	30	24	.585	29	36	23	32	25	.862	−.277
3	27	28	24	28	19	.704	38	28	22	22	27	.711	−.007
4	40	68	24	28	34	.850	56	35	34	34	31	.554	.296
5	44	39	41	41	26	.591	54	42	34	39	30	.556	.035
6	32	49	32	21	24	.750	30	23	31	27	16	.533	.217
7	35	35	25	33	35	1.000	40	16	23	33	28	.700	.300
8	29	32	39	62	39	1.345	31	38	26	35	41	1.323	.022
9	28	25	40	25	35	1.250	33	36	28	24	28	.848	.402
10	30	21	17	30	30	1.000	30	33	29	22	29	.967	.033
11	45	45	34	52	32	.711	30	35	29	28	27	.900	−.189
12	25	35	26	36	25	1.000	33	42	22	26	19	.576	.425
13	26	21	28	29	30	1.154	20	21	25	21	15	.750	.404
14	36	37	46	64	28	.778	41	39	40	31	21	.512	.266
15	21	19	17	20	25	1.190	20	16	24	16	19	.950	.240
16	45	40	32	37	31	.689	30	34	34	32	33	1.100	−.411
17	19	23	26	20	17	.895	20	25	17	22	19	.950	−.055
18	29	28	42	56	40	1.379	45	55	51	35	28	.622	.757
19	38	49	48	54	31	.816	28	16	22	18	19	.679	.137
20	47	35	45	28	34	.723	29	30	48	37	22	.759	−.036
Total	676	728	650	722	588	18.154	688	650	594	567	513	15.558	2.597
N:20 Mean	33.80	36.40	32.50	36.10	29.40	.9077	34.40	32.50	29.70	28.35	25.65	.7779	.1298
S.D.	8.18	11.70	8.48	13.60	5.56	.242	10.34	10.29	8.54	6.32	6.92	.210	
S.E. Mean				3.12		.055				1.45		.048 Fisher's t 1.21 Probability = 1–1.5 chances in 100	

wrong responses than they did to learn the correct response. Guthrie's statement (4, p. 72) that it takes only one association to learn and that the remaining association trials are necessary to unlearn all the other responses that have been associated automatically (generalization) might apply here.

In general, the results of the present experiment establish the point under consideration. Learning of new responses to old stimuli interferes markedly with the ability to recall the original responses. This finding, of course, adds nothing new in theory and should be considered primarily as a demonstration of a principle. The value of the results lies in the specification of the substitute responses which have replaced the original responses.

Experiment II.—A demonstration of the same principle by comparison of groups with the identical test material.

In the discussion of the previous experiment, it was pointed out that it seemed justifiable to assume equal difficulty of control and experimental materials. The close correspondence of the means of the trials necessary for learning the first sets in both sessions bore out that assumption. It was desirable, however, to attempt a procedure in which both experimental and control groups would learn exactly the same materials, at least with respect to beginning sets. Obviously this would be impossible with the same individuals as subjects for both sessions, as they already would have learned those syllables in one session when they came to the next. For this reason an experiment was designed in which different groups of students (equated for nonsense syllable learning ability) served as subjects.

In this procedure the experimental subjects learned four sets of paired associates (ten pairs to a set). (See Table III.) Here, again, the first syllables in each pair for each set were exactly the same. After learning four different associates to the same syllables the subjects were asked to recall the first responses. The control subjects learned as their first set of pairs the very same syllables as did the experimental subjects; their next three sets, however, were composed of independent, different pairs of associates so that no deliberate confusion or interference was possible. After learning these new sets of pairs, the control subjects were asked to recall the first sets. The difference in the relative ease or difficulty of recall between the two groups would then be a measure of the interference effects of new associations to old stimuli.

In this experiment paired nonsense syllables were mimeographed on slips of paper 2″ × 11″. Ten pairs of syllables appeared on the top third of the slip. The middle third of the slip was blank and the bottom third contained the first halves of the pairs in the top third with spaces for recording the corresponding associates. The order of syllables in the bottom third was different from that in the top third and the subjects were duly informed about this and urged to learn the pairs as pairs and not in order down the list. The slips were so folded that upon lifting the top fold the pairs were exposed for learning and the answer sheet was covered. When the signal was given to stop learning, the pairs were covered and the answer sections exposed. The subjects were first instructed in the procedure by a preliminary session with a practice set of syllables. This practice session also served as a basis for dividing the subjects into groups of relatively equal learning ability. The same number of good, bad, and indifferent learners was placed in each group. After the groups were selected, each subject received a packet containing five folded slips labelled on the outside with the order in which he was to learn the separate slips.

TABLE III

SYLLABLES USED FOR EXPERIMENTAL GROUP—EXPERIMENT II

I	II	III	IV	V
toc-nem	nog-waf	dil-miv	ref-tos	lav-nid
ref-cir	kor-bap	lun-tex	dil-ror	nir-lat
dil-boz	dil-bol	kor-bof	teb-lin	cel-tus
teb-sor	ref-cum	cel-ren	lav-raf	ref-cir
nog-kez	toc-nop	tog-rul	nir-lor	nog-kez
lav-nid	cel-tep	nog-maf	nog-bon	toc-nem
kor-zel	teb-pos	teb-cer	toc-cet	lun-bax
cel-tus	lun-cot	nir-kol	cel-nur	teb-sor
lun-bax	nir-dax	ref-nox	kor-nak	kor-zel
nir-lat	lav-mur	lav-cal	lun-tis	dil-boz

Order of Recall of Above

kor-____	lun-____	nir-____	cel-____	cel-____
nog-____	toc-____	kor-____	teb-____	nog-____
lun-____	nog-____	cel-____	lun-____	teb-____
toc-____	teb-____	ref-____	kor-____	dil-____
teb-____	kor-____	lun-____	dil-____	toc-____
ref-____	cel-____	teb-____	lav-____	kor-____
cel-____	nir-____	lav-____	nog-____	nir-____
nir-____	dil-____	nog-____	ref-____	ref-____
lav-____	ref-____	dil-____	toc-____	lav-____
dil-____	lav-____	toc-____	nir-____	lun-____

SYLLABLES USED FOR CONTROL GROUP

I	II	III	IV	V
Same as above	dob-waf	leb-miv	ced-tos	Same as above
	kev-bap	vib-tex	geb-ror	
	sar-bol	nad-bof	baz-lin	
	wix-cum	gog-ren	hin-raf	
	kaz-nop	cos-rul	tix-lor	
	fim-tep	gar-maf	fef-bon	
	zul-pos	nal-cer	rol-cet	
	gor-kot	pem-kol	ris-nur	
	ter-dax	bom-nox	dir-nak	
	rad-mur	fer-cal	sem-tix	

Order of Recall of the Above

Same as above	gor-____	pem-____	ris-____	Same as above
	kaz-____	nad-____	baz-____	
	dob-____	gog-____	sem-____	
	zul-____	bom-____	dir-____	
	kev-____	vib-____	geb-____	
	fim-____	nal-____	hin-____	
	ter-____	fer-____	fef-____	
	sar-____	gar-____	ced-____	
	wix-____	leb-____	rol-____	
	rad-____	cos-____	tix-____	

After preliminary experimentation it was decided that three minutes was a satisfactory learning period for partial mastery of the lists. It was necessary to eliminate the possibility of some subjects learning all of the syllables since there could then be no prospect of improvement for the controls and only the prospect of decrement for the experimental subjects. The most desirable interval would be one in which the average subject would learn about half the pairs. As will be observed in the results, the subjects did learn approximately this number. The subjects were told to use any method of learning they liked but not to shift from one technique to another during the experiment. It was suggested that they all use a uniform method of reading over the list three times and then anticipating by covering the first halves of the pairs; it was further suggested that they try anticipating from each end and in both directions from the middle so as not to learn the pairs in order. Three minutes were allowed for learning each list. After each learning period, one minute was allowed to record the responses and two minutes of rest followed before the next slip was studied. After all four lists were learned the subjects were instructed to study list No. 5 (same for both groups) which contained the same pairs, in a new order, that they had studied first. They were told that the syllables were the same as in the first set. The time allowed was 1½ minutes (subjects were not told that the time would be shorter, but all noticed this fact).

Although this experiment is not concerned with the difficulty of the material intervening between the first and final learning of the first sets, it was decided to vary the order of appearance of sets 2, 3, and 4, so that an equal number of subjects would start and finish with different arrangements of the 2, 3, and 4 combinations.

Subjects.—Eighty college sophomores of both sexes served as subjects. They were divided into two groups (experimental and control) of forty each; one subject was dropped from each group for failure to learn even one syllable in the first learning trial. The subjects' familiarity with nonsense materials was limited to the present experiment; they had no knowledge of the purpose of the experiment. The subjects met in an ordinary class-room in groups of forty (twenty control and twenty experimental) and all received the same instructions to learn as many pairs of syllables as possible in each trial. The subjects were not paid.

Results

The results of the second experiment follow the same general trend as do the results of the first. The means for control and experimental groups are almost exactly equal for the first set of syllables (same for each group). (See Table IV.) When these sets were recalled following the learning of interpolated material it was found that the experimental group suffered a slight loss (.154 syllables on the average) while the control group gained 1.46 on the average. The difference between experimental group loss and control group gain is reliable (critical ratio = 3.87). None of the differences between other sets are significant and there is no point to comparing trends between the different groups because they learned different interpolated materials.

This second experiment substantiates the first and has some slight advantage over the first as far as interpretation is concerned since in this case two groups are compared on exactly the same original responses, a condition which could not be met in the first experiment where each subject served as his own control. Again the subjects tended to commit errors of reversion and intrusion and occasionally compromise errors, but these were not frequent enough to warrant tabulation.

TABLE IV

THE NUMBER OF SYLLABLES IN EACH GROUP LEARNED BY THE EXPERIMENTAL (INTERFERENCE) SUBJECTS AND THE CONTROL (NON-INTERFERENCE) SUBJECTS

Subject	Experimental						Control					
	Set I	Set II	Set III	Set IV	Recall Set I	Loss or Gain (V–I)	Set I	Set II	Set III	Set IV	Recall Set I	Loss or Gain (V–I)
1	2	7	4	10	1	−1	2	2	2	3	2	0
2	2	3	2	5	7	5	2	4	3	3	5	3
3	2	3	3	1	0	−2	2	3	4	1	1	−1
4	2	3	3	3	2	0	2	8	0	3	6	4
5	2	2	4	4	3	1	3	6	4	4	5	2
6	2	3	2	3	3	1	3	1	4	6	7	4
7	2	4	4	2	2	0	3	4	4	2	5	2
8	2	2	5	1	2	0	3	2	3	5	3	0
9	2	2	5	4	1	−1	3	3	3	2	1	−2
10	3	3	2	4	3	0	3	2	2	1	4	1
11	3	3	4	6	4	1	3	4	4	4	3	0
12	3	2	7	3	1	−2	3	4	3	8	6	3
13	3	3	3	1	3	0	3	7	5	4	6	3
14	3	4	7	4	2	−1	3	5	1	3	4	1
15	3	4	4	3	3	0	4	5	3	2	5	1
16	4	3	4	4	4	0	4	2	3	3	7	3
17	4	5	1	4	3	−1	4	7	2	7	5	1
18	4	4	2	6	6	2	4	6	8	2	4	0
19	4	7	7	5	4	0	4	8	4	8	10	6
20	4	4	6	9	8	4	4	5	4	2	7	3
21	4	1	6	7	5	1	4	5	2	2	7	3
22	4	3	6	5	4	0	4	3	2	0	4	0
23	5	1	4	3	5	0	4	5	6	4	9	5
24	5	4	7	4	4	−1	5	8	5	4	8	3
25	5	1	2	1	3	−2	5	2	5	3	7	2
26	5	7	5	10	4	−1	5	3	3	3	6	1
27	6	5	4	5	4	−2	5	9	3	5	10	4
28	6	3	6	7	4	−2	5	10	8	9	7	2
29	6	8	4	9	4	−2	5	5	3	4	5	0
30	6	9	7	5	7	1	5	6	5	7	6	1
31	6	4	5	3	5	−1	5	5	4	7	5	0
32	6	10	8	8	7	1	5	3	7	6	2	−3
33	6	7	1	2	5	−1	6	7	8	10	10	4
34	6	9	6	6	8	2	6	8	2	6	3	−3
35	6	5	6	8	7	1	6	4	6	7	7	1
36	7	6	3	9	6	−1	7	6	8	6	8	1
37	8	5	5	1	9	1	8	8	6	6	10	2
38	9	0	6	5	6	−3	8	9	6	8	7	−1
39	9	7	7	8	6	−3	8	8	8	8	9	1
Mean	4.36	4.28	4.54	4.82	4.23	−.154	4.31	5.18	4.18	4.56	5.79	1.46
S.D.	1.91	2.38	1.85	2.60	2.26	1.66	1.60	2.33	2.06	2.45	2.42	2.01
S.E.						.266						.322

Difference between Experimental Group Loss and Control Group Gain:
1.462 − (−.154) = 1.616
Standard Error of Difference = .417
Critical Ratio = 3.87

The second experiment can be performed in less than an hour with large classes and can therefore serve as a class-room demonstration of the principles involved.

Discussion

In both experiments, the same general results were found. Learning new responses to old stimuli results in an impairment or weakening of retention of the original response. This, of course, is not a new theoretical principle. The present experiment, however, permits the identification of the new responses which take the place of the old. It is presumed that the essential conditions stipulated by Guthrie in the introduction have been met. As such, the results might be acceptable as further support for the interference theory of extinction or forgetting. Gibson's (**3**) paper on the generalization of inhibition in retroactive inhibition raises the question as to whether generalization of inhibition can be demonstrated in a discrimination situation. She asks: "But has the extinguished response been inhibited for its own stimulus of the first list, its positive stimulus?" The present results suggest that such differential inhibition has indeed been generalized to the first response. The subjects are unable to recall the original response, and for at least eight of twenty subjects in the first experiment the original set seemed strange and new and was as difficult to relearn as it was to learn originally. If future studies confirm the present results, the mechanism of retroactive inhibition or forgetting may eventually be laid bare, at least theoretically.

No attempt will be made in the present paper to discuss systematically the more theoretical aspects of the results. Gibson's excellent discussion covers most of the present findings. It is too easy to begin to generalize about forgetting, amnesia, retroactive and other kinds of inhibition. On the basis of the present results and observations of the subjects in their struggles, the writer is inclined toward the view that to speak of inhibition at all is to attack the problem in a negative way. It involves the assumption of some principle or mechanism which seems, as far as the present experiment is concerned, gratuitous. The subjects in this experiment seemed to be unable to recall an old association not because it had been inhibited (except in a purely descriptive sense), but because some other response was stronger and was given either overtly or implicitly while the subject remained silent for fear of making an error.

A large amount of such wrong associating undoubtedly goes on while the subject is learning any one list, including the first. At times, a subject would respond with the same syllable to three or

even four stimulus syllables in succession, without being able to prevent the to-them-absurd repetitions. In the words of one subject, "I just kept thinking of 'pem' and couldn't get it out of my head even though I knew it was wrong." The situation finds an analogue in the embarrassed guest at a reception who promptly forgets the names of all the people he has just met. It seems to the present writer that, in such a situation, the names (responses) are not forgotten so much as they are attached to the wrong people (stimuli). The real question is perhaps not "What is this man's name?" but rather, "Which of these men is Mr. Jones, Mr. Smith, and Mr. Brown?" Further study is needed of the ways in which a single list of paired associates (or other multiple reactions) is learned from the point of view of the interferences involved before the problem is complicated by interpolated learning material. Hovland's (**6**) study of randomly presented paired associates represents the type of approach that might help solve this problem.

Summary and Conclusions

Two experiments were conducted with a procedure which specified the responses which are substituted for originally learned stimulus-response sequences when such original sequences are forgotten. In the first experiment, twenty subjects learned four lists of nonsense syllables in paired-associate arrangements. The first syllables (stimuli) in each list were the same throughout; the second syllables of each pair (responses) differed. After learning three new responses to the same 'old' stimuli, the subjects were unable to recall the original responses and took significantly more trials to relearn the original responses than they did when recalling control lists of equal difficulty.

In the second experiment 80 subjects, divided into control and experimental groups, learned four lists of nonsense syllables, again in paired associate form, 10 pairs to each list. The first list was the same for each group. The experimental group then learned three new sets of responses to the stimulus syllables of the original set; the control group learned three distinctly different sets. The experimental group suffered a slight loss in relearning the original responses while the control group gained. The difference between the relearning scores is significant.

In general, the results demonstrate or identify in a more direct fashion than do the customary retroactive inhibition experiments the responses which have blocked or taken the place of original responses when those responses cannot be recalled.

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SOME ELECTROENCEPHALOGRAPHIC CORRELATES OF INTELLIGENCE IN EIGHT-YEAR- AND TWELVE-YEAR-OLD CHILDREN[1]

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Due to the fact that the electroencephalogram (EEG) represents one type of cortical activity, there have been repeated attempts to correlate this activity with other types, usually called 'psychological activity.' Such correlations may be attempted by one or the other of two experimental approaches: direct correlation between EEG activity and temporally simultaneous psychological activity; or, correlation between an average, and presumably constant, EEG characteristic and an average, and likewise presumably constant, psychological characteristic (**9**). The EEG correlates of what is called 'intelligence' may be approached by either line of attack; in the first instance, the electroencephalogram would have to be recorded *during* activity which could be labelled 'intelligent,' and the correlation expressed in terms of variations along two continua, one physiological, the other behavioral; in the second instance, some supposedly repeatable EEG measure, such as *alpha index*, or *alpha frequency*, or some other measure would have to be correlated with some generalized score expressive of the capacity of the individual to respond,

[1] This is one of a series of papers (from the Laboratory of Physiological Psychology, Department of Psychology, University of Iowa) under the direction of the senior author, dealing with physiological correlates of psychological processes.

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such as the I.Q. At the present time, the only studies relating 'intelligence' and the electrophysiological measurements of cortical activity have used the second approach, due, perhaps, to the inferences which may be drawn from data pertaining to the development of the EEG in childhood.

Although the EEG is composed of a continuous series of frequencies, there is a dominant rhythmic phenomenon which in the *adult* appears at a frequency of ten cycles. The range of frequencies which may be classified in this band extends from 7.5 to 12.5 per second, there being some variation from person to person in this value. This particular rhythm has been designated the *alpha rhythm.* In children, however, such rhythmic activity appears at lower frequencies than ten cycles; at three months of age it first appears at four cycles per second; and the 'adult' value is not reached until ten to twelve years of age (**9, 14, 15, 16, 22, 23, 24, 25**). In children, as in adults, there is individual variability in the frequency of the alpha rhythm. In Fig. 1 (plotted from data published by Lindsley,

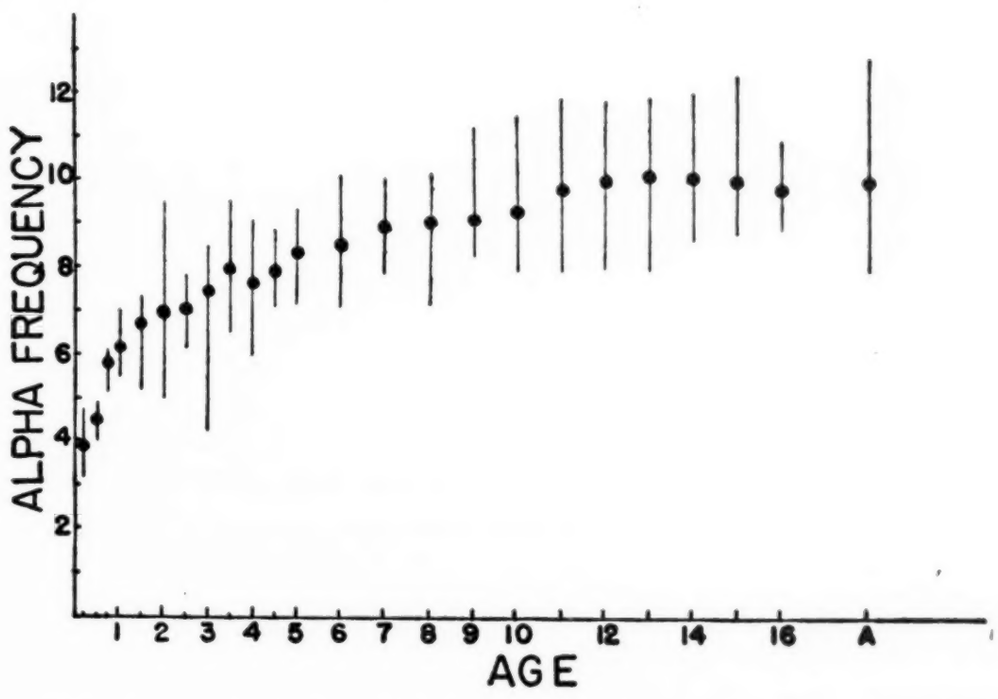

FIG. 1. Alpha frequency *vs.* chronological age. Dots, mean values; bars, range of values. (This figure is based upon data from Lindsley, 15.)

16) the *mean* frequency of the alpha rhythm from three months of age to adulthood is presented, together with the *range* of values at each age level.

In addition to measurements of the frequency of alpha, the percentage of time the alpha rhythm appears on the record may also be computed. There is a wide range of percent time alpha (alpha

index) possible, the limits being zero to one hundred. According to some workers (**3**), alpha index is constant for a given individual. Lindsley has reported, however (**15**), that this score decreased slightly with age.

The question easily is asked concerning the variable to which these variations in EEG characteristics may be attributed. Is the change in the alpha frequency, or the alpha index, the result of change in chronological age alone, or does the increase in mental age which normally accompanies an increase in chronological age have a part in determining these electrocortical variations?

Kreezer, who has conducted the most comprehensive investigations of the relationship between mental level and the EEG, has reported that some of the changes in *alpha* may be due to this variable of intelligence level. His major findings may be grouped under two headings: the relationships as they appear in the Mongolian type of mental deficiency; and as they appear in the non-differentiated familial type of mental deficiency. Kreezer controlled what might otherwise be the disturbing factor of chronological age by selecting for study only *adult* cases (those above sixteen years chronological age) who had presumably reached their maximum alpha frequency and whose alpha index was presumably stable.

In the Mongolian deficients (**12**) a correlation of $-.21$ was obtained between mental age and alpha frequency, while a correlation of $+.35$ was obtained between mental age and alpha index. (The latter correlation was statistically significant, the former was not.) The relationships found were thus not those which would be predicted from the study of normal children, but were instead the very opposite.

In the non-differentiated type of mental deficiency (**13**), which is assumed to represent the lower end of the 'normal' curve of mental ages, correlations of $+.32$ between mental age and alpha frequency, and $+.16$ between mental age and alpha index were obtained. (The first of these is 'marginally' significant, the latter is not significant.) In the case of alpha frequency, there is a parallel between normal development and the data based on the feeble-minded group.

Other studies attempting to study the relation between *alpha index* and intelligence level (**15**, **19**) have met with a lack of success.

Kreezer's investigations of the non-differentiated type of deficient indicate (*a*) that there very likely is no relationship between the percent time the alpha rhythm appears (alpha index) and intelligence level, and (*b*) that there probably is a slight positive relationship between the frequency of the alpha rhythm and intelligence level. However, these studies have been confined to the *lowest* levels of the intelligence continuum, and it is possible that results based on a

sampling of the full range of the intelligence continuum would lead to different conclusions.

Problem

The present investigation differs from those reviewed chiefly in the selection of subjects. We were interested in determining the degree of relationship between the EEG variables of alpha frequency and alpha index when intelligence level was varied widely. This range appeared more easily obtained in a sample of children than in a sample of adults. A study confined to children offered other advantages, in that Kreezer had earlier reported (**11**) that certain of the relationships seemed to pivot about a mental age of eight years; and Hinton (**6**) has reported that correlations between basal metabolic rate and intelligence level decrease markedly as age increases, the critical point being ten years (chronological age). In view of these factors, this investigation has been restricted to a study of the alpha phenomena of the EEG and their relationship to intelligence level in a sample of children. Two groups were selected, one with a chronological age of eight years, the other, of twelve years. In both groups, while chronological age was strictly controlled, mental age varied widely.

Subjects

Forty-eight children, whose chronological ages fell between the limits of 7.5 and 8.5 years, served as subjects in the first group. These were divided into three sub-groups.

Sub-group I.—This group was composed of twenty children enrolled in the University of Iowa Elementary School. The mean chronological age of this group was 8.1 years. The mean I.Q. was 127 (range, 100 to 171).

Sub-group II.—This group was composed of nineteen children in residence at the Iowa Soldiers' Orphans' Home, at Davenport, Iowa. The mean chronological age was 8.1 years; the mean I.Q. was 87 (range, 74 to 102).

Sub-group III.—This group was composed of nine children in residence at the Hospital for Epileptics and School for Feeble-minded, at Woodward, Iowa. The mean chronological age was 8.2 years; the mean I.Q. was 51 (range, 30 to 71). These subjects were selected so that none exhibited neurophysiological disorders to which the low intelligence level could be attributed. All epileptics, post-encephalitics, Mongolians, etc., were excluded.

Forty-two children served as subjects in the twelve-year-old group. Their chronological ages fell between 11.5 and 12.5 years at the time of the EEG recording. They were selected from three different schools, which formed a sub-grouping as follows:

Sub-group I.—This group was composed of eighteen children in residence at the Iowa Soldiers' Orphans'Home, at Davenport, Iowa. The mean chronological age was 12.0 years; the mean I.Q. was 87.9 (range, 56 to 119).

Sub-group II.—This group was composed of six children enrolled in the University of Iowa Junior High School. The mean chronological age was 11.9 years; the mean I.Q. was 122.6 (range, 104 to 145).

Sub-group III.—This group was composed of eighteen children enrolled in the Iowa City Elementary and Junior High Schools. The mean chronological age was 12.1 years; the mean I.Q. was 125 (range, 99 to 153).

For the entire sample the mean chronological age was 12.1 years; the mean I.Q. was 108.8 (range, 56 to 153).

The subjects at the upper end of the intelligence scale were selected mainly from the Iowa City public school system to avoid any unknown selective factors that might be operating in a restricted school such as the University school, and which provided all of the superior children in the eight-year-old sample.

Relationships at the Eight-Year Level

Apparatus and Procedure

Standard high-gain, low-frequency amplifiers were used for recording. Ink records were made with the Grass oscillograph, the recording speed being 30 mm per second (the tape being driven by a synchronous motor). The leads were of the lead plate type, and were monopolar to the mid-occiput. Continuous records were made over a period of five minutes. In case a child had difficulty in keeping the eyes closed during the recording, a blindfold was employed.

In the analysis of the records all potentials falling within the limits of 7.5 to 12.5 per second were counted as alpha waves. (These limits were selected to conform to those of Kreezer, 12, 13.) The number of such waves falling in ten randomly selected seconds of record was averaged to give alpha frequency. The percentage of a three meter sample of record occupied by such waves was computed to give the alpha index.

The intelligence quotient was determined by means of individual revised Stanford-Binet tests (except at the lowest levels, at which the Kuhlman-Binet was employed).

Results

Table 1 presents the means and ranges of both EEG measures for each of the three groups of eight-year-old subjects. Figure 2 presents the values of alpha frequency *vs.* intelligence level.

TABLE 1

Mean Occipital Alpha Frequency and Mean Occipital Alpha Index, Eight-Year-Old Children

Sub-group	N	Alpha Frequency		Alpha Index	
		AM	Range	AM	Range
I (Elementary school).....	20	9.52	8.0–10.2	32.9	2–81
II (Orphanage school).....	19	8.66	7.7–10.4	47.0	15–73
III (Feeble-minded school)...	9	8.71	8.5– 9.1	20.4	1–65

These groups were tested for homogeneity with respect to alpha frequency and alpha index by the analysis of variance. Treatment of alpha frequency yielded $F = 10.74$ (significant at the one percent level of confidence). Treatment of alpha index yielded $F = 4.39$ (significant at the five percent level of confidence).

When the mean alpha frequencies of Sub-groups I–II, I–III, and II–III were compared, the first two differences were significant, while the last was not significant. When the mean alpha indexes of the same groups were compared, only the last difference was found to be significant.

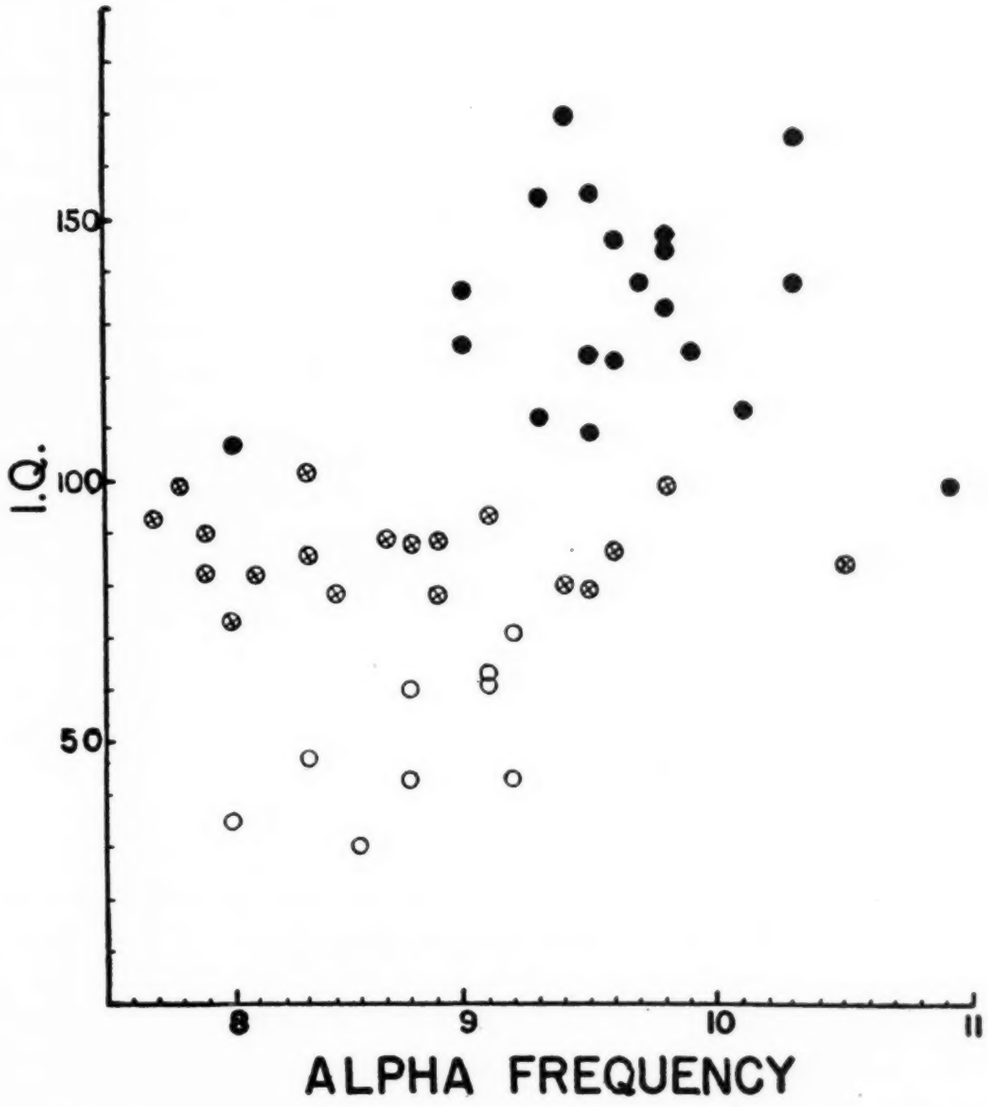

FIG. 2. Alpha frequency *vs.* intelligence quotient at 8 yr. chronological age. Filled circles, University school; crossed circles, orphanage; open circles, feeble-minded home.

Product-moment correlations between I.Q. and alpha frequency (AF) and between I.Q. and alpha index (AI) were as follows:

r(IQ, AF) = +.50 (significant at the one percent level)
r(IQ, AI) = +.23 (not significant at the five percent level)

In order to isolate possible uncontrolled factors attributable to chronological age, the following correlations were computed:

r(CA, IQ) = −.01 (not significant)
r(CA, AF) = −.11 (not significant)

Since neither of these last two correlations was significant, it appears that chrological age, *per se*, did not, in this sample, spuriously increase the correlation between intelligence level and alpha frequency.

It appeared, however, that another variable could possibly have influenced the data. The ink-writing oscillograph employed in recording the EEGs was driven by a synchronous motor, the absolute speed of which is governed by the frequency of the driving A.C. line. This frequency was presumed to be, in the localities in which recording was done, sixty cycles. However, if a consistent variation had been present in one locality and not in the others, the measurements, which were based on the assumption of a constant speed of the recording tape, *could* have been systematically altered to produce the correlation found between I.Q. and the frequency of the alpha rhythm.

To rule out the disturbing possibility that this variable was operating, eight of the children of Sub-group I, eleven of the children of Sub-group II, and eight of the children of Sub-group III were re-recorded by one of us (J. R. K.[3]) at a later date. The children in Sub-groups I and II were selected in terms of alternate positions in I.Q. rank. These records were secured with amplifiers of the same type as those previously used, but the recording was by means of a Westinghouse optical oscillograph, on sensitized paper. A known fifty-cycle time line was included on the record (generated by a General Radio low-frequency oscillator which was calibrated against U. S. Bureau of Standards broadcasts). Thus it was no longer necessary to make the assumption that 30 mm distance on the recording tape equalled one second of recording time. Two samples of the mid-occipital EEG were taken, each 30 seconds in length, and these were separated in time by a period of five minutes. (Ink records were simultaneously recorded for monitoring purposes.)

The film records were analyzed by measuring the duration of each of twenty-five alpha waves in each sample; these values were averaged and the average was converted to frequency $\left(f = \frac{1}{\alpha d}\right)$. The correlation between this value and I.Q. was $+.66$ ($N = 27$).

When the original data secured on these same twenty-seven subjects were subjected to correlation, $r(\text{IQ, AF}) = +.49$. Due to differences in the intervals between recordings, Sub-group I was, at the time of the second recording, an average of three months older than either of the other groups (which were still equal with respect to chronological age). Holding chronological age constant by partial correlation, $r(\text{IQ, AF}) = +.61$ [$r(\text{IQ, CA}) = +.29$; $r(\text{CA, AF}) = +.41$].

Having thus demonstrated that the possible artefact of variation in recording speed did not account for the obtained correlation between frequency of the alpha rhythm and intelligence level, certain

[3] The assistance of H. D. Hadley and P. E. Griffith in obtaining these records is gratefully acknowledged.

aspects of the data may be reviewed. From Fig. 2 it is seen that there is a different relationship between the two variables in each of the three groups of subjects which together composed the total sample. Sub-group III, that with the lowest intelligence level, appears to exhibit a more linear relationship than do the other groups. Within this group, r(IQ, AF) = +.63. This value, however, should be evaluated in terms of N, which is nine. In Sub-group II there is no linearity in the relationship; r(IQ, AF) = .00. Group I, that with the highest intelligence level, likewise shows no trend toward a linear expression of the relationship; r(IQ, AF) = +.04. When Sub-groups I and II are combined, however, r(IQ, AF) = +.47, which is approximately the value for the sample as a whole.

Relationships at the Twelve-year Level

Apparatus and Procedure

Standard high-gain, low-frequency amplifiers were used for recording. Records were made with a multiple-element Grass ink-writing oscillograph, the recording speed being 60 mm per second (the tape being driven by a synchronous motor). A known fifty-cycle time line was included on the record, generated by a General Radio low-frequency oscillator which was calibrated against U. S. Bureau of Standards broadcasts. The electrodes were of the lead plate type and were monopolar to the mid-occipital and mid-motor areas. Two neutral electrodes leading from the lobes of the ears were used. Continuous records were made over a period of five minutes.

In the analysis of the records two 30 cm strips were selected, one near the beginning and one near the end of the record. The duration of each wave within the total 60 cm of record was measured from the time line in hundredths of a second.

The mean alpha frequency $\left(f = \frac{1}{\alpha d}\right)$ was determined from the mean duration of all waves analyzed for each area. 'Alpha' frequency was derived from those waves with durations between .08 and .13 seconds inclusive.

Since neither at the adult nor at the eight-year level has alpha index been found to be related to intelligence level, this measure was not made at the twelve-year level. The intelligence quotient was determined by means of individual Revised Stanford-Binet (Form L) tests administered within 12 months prior to the EEG recording.

Results

Tables 2 and 3 present the means and ranges for the alpha frequencies measured from the occipital area and the motor area. Figure 3 is a plot of occipital alpha frequency *vs.* intelligence level (I.Q.) for all twelve-year olds studied.

The product-moment correlation between I.Q. and alpha frequency (AF) for the occipital area was +.12; for the motor area the correlation was −.08.

These findings indicate that within this sample there is no demonstrable relationship between the electrocortical frequencies, as measured, and intelligence level.

TABLE 2

MEAN OCCIPITAL ALPHA FREQUENCY, TWELVE-YEAR-OLD CHILDREN

Sub-group	N	AM	Range
I (Orphanage school).....	18	9.8	8.6–11.2
II (University school).....	6	9.9	9.1–10.5
III (Public schools).....	18	9.8	9.1–11.2

TABLE 3

MEAN MOTOR ALPHA FREQUENCY, TWELVE-YEAR-OLD CHILDREN

Sub-group	N	AM	Range
I (Orphanage school).....	18	9.9	9.2–10.6
II (University school).....	6	9.9	9.1–10.3
III (Public schools).....	18	9.7	9.0–10.2

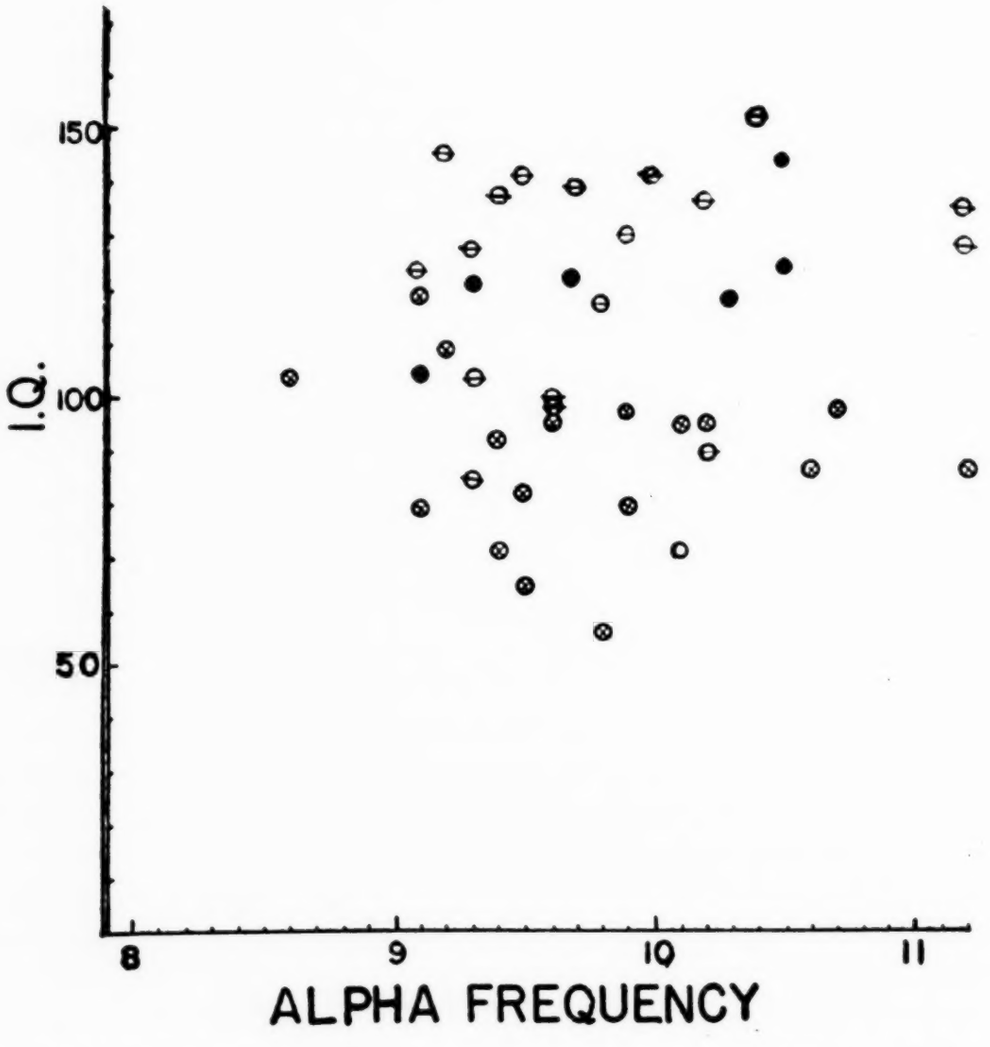

FIG. 3. Alpha frequency *vs.* intelligence quotient at 12 yr. chronological age. Filled circles, University school; barred circles, public school; crossed circles, orphanage.

Discussion

The conflicting sets of data at the eight-year- and at the twelve-year-old levels are somewhat difficult to evaluate, for one cannot state that there is or that there is not any relationship between alpha frequency and intelligence level. The existing evidence would indicate that there is a relationship at the eight-year level (this report) and at the adult level (Kreezer, **13**), and that there is no relationship at the twelve-year-old level (this report).

At least two hypotheses may be brought forward to account for the discrepancy between the twelve-year data, and the eight-year and adult data.

The first hypothesis would account for the conflicting data in terms of sampling error. Thus, if it is temporarily assumed that a relationship between alpha frequency and intelligence level *does* exist, the observed zero correlation at the twelve-year level can be accounted for by chance. That is, this zero correlation may have been drawn from the lower end of the distribution of possible correlation coefficients. Contrariwise, if it is temporarily assumed that there is *no* relationship between the variables, the significant correlations at the eight-year and at the adult levels can be accounted for by chance, these correlations having possibly been drawn from the high end of the possible distribution of such correlation coefficients.

A third hypothesis may also be invoked in the attempt to order these data. This would account for the zero correlation at the twelve-year level in terms of apparently well-substantiated findings that, at about that age level, the EEG underoges certain non-permanent changes in its frequency characteristics. Such changes are clearly shown in Fig. 1. This is the age usually associated with the beginning of adolescence, and the changes taking place within the human organism during this period appear to be reflected in part in the electrophysiological indexes of cortical activity. The nature and the extent of these changes are neither definitely nor completely known, but the development of cortical activity is clearly altered. An examination of the data of Smith, of Lindsley, and of Knott and Gibbs reveals a change in alpha frequency at or near the beginning of adolescence. These observations indicate that there is a basis for at least suspecting that such an alteration in alpha frequency may interfere with the expression of the relationship between it and intelligence level.

Just exactly what the factors involved may be which at this age disrupt a possible relationship, cannot be stated. Since basal metabolic rate (BMR) and alpha frequency correlate +.90 (Lindsley and Rubenstein, **17**), one might suspect that alterations in BMR at the

adolescent level could be involved. However, Boothby and Sandiford (**2**) do not find any increase in BMR at adolescence. Other endocrine changes may, however, be involved in the variability of alpha frequency.

If one were to accept the first or the third hypothesis as suggestive for further investigation, one would then be able to set up a further working hypothesis accounting for any reported relationships between the variables in terms of frequency characteristics as an index to cerebral states which limit the performance of the organism. Since there seems to be some reason to believe that certain frequency characteristics of the EEG are related to the complexity of concurrent behavioral processes (**8**) this is at least conceivable.

Summary and Conclusions

1. The relationship between occipital area alpha frequency, and alpha index, and intelligence level has been investigated in a sample of forty-eight eight-year-old children especially selected to represent a wide range of intelligence levels. The relationship between occipital and motor area alpha frequency and intelligence level has been investigated in a sample of forty-two twelve-year-old children similarly selected but having a slightly narrower range of intelligence levels.

2. At the eight-year level the correlation between alpha frequency and intelligence level was +.50; that between alpha index and intelligence level was +.23. Only the first of these is statistically significant.

3. At the twelve-year level the correlations between occipital alpha frequency, and motor alpha frequency, and intelligence level were +.12 and −.08, respectively. Neither of these is statistically significant.

4. Three hypotheses have been suggested to account for the conflicting results. The first two suggest that sampling error may be equally responsible for the 'significant' and the 'non-significant' correlations. The third suggests that at the twelve-year level organic changes associated with adolescence may alter an otherwise significant positive correlation.

5. These hypotheses may be tested by further research; and it is to be urgently suggested that any present conclusions regarding the relationship of EEG variables and intelligence level be regarded as tentative until full exploration and attendant confirmation or rejection of these hypotheses be accomplished.

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FACTORS PRODUCING GENERALITY IN THE LEVEL OF ASPIRATION *

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A basic problem in the investigation of the level of aspiration is the degree of similarity of an individual's aspiration responses in different situations. This is the problem of *the generality of the level of aspiration.* The purpose of the present study is to discover certain of the factors which contribute to greater or less generality as the level of aspiration is measured under laboratory conditions.

The index of the degree of generality is the amount of correspondence among measures of aspiration behavior in different situations. In the present research, levels of aspiration set by a subject on different laboratory tasks have been compared by the correlation technique.

The results of previous investigations of generality have tended to vary according to the experimental conditions employed. The studies concerned primarily with the effect of success and failure on the level of aspiration (**9**, **10**, **12**, **13**) have, for the most part, reported a high degree of correspondence between reactions to success and failure in the laboratory and in life situations. These results may be due to the fact that, like real life situations, the laboratory situations that have been employed have had considerable ego-value for the subjects. For example, Sears (**13**) used reading and arithmetic tests as laboratory tasks; these were given in a school situation to children who had experienced consistent success or failure on reading or arithmetic in their school careers. Similarly, Hoppe (**10**) made the laboratory situation approximate the non-laboratory situation by using as subjects students whom he knew well; under these conditions success or failure on the experimental tasks may have had personal significance for the subject because of the prestige relationship between subject and experimenter. On the other hand, studies which have correlated aspiration scores and broad personality trait scores (**5**, **7**) have shown little evidence for generality. Gardner (**7**), for instance, found very low inter-correlations between a subject's

* This is an abridgment of a dissertation presented to the Faculty of the Graduate School of Yale University in candidacy for the degree of Doctor of Philosophy in Psychology. The writer wishes to express her appreciation of the suggestions given her throughout the experiment by Dr. Robert R. Sears.

aspiration scores on laboratory tasks and his scores on various personality traits. The subjects were rated on the traits attributed by Lewin's students to individuals showing different aspiration response patterns. Gardner's results are not surprising in view of the fact that the same aspiration score has been found to be related to different traits in different individuals (**8, 13**).

Several investigators (**4, 6, 8**) have measured generality by correlating aspiration scores secured on different laboratory tasks. The results and conclusions of these investigators also are not in agreement. Frank (**4**) considered that a subject's aspiration score on a laboratory task would be representative of his aspiration response in all situations. His data, however, are not entirely conclusive since his correlations are based on the scores of only twelve subjects, each of whom performed only two different tasks. Gould (**8**) and Gardner (**6**) used an adequate number of tasks and subjects but obtained conflicting results. Since the correlations Gould obtained ranged from .04 to .44, she concluded that there was no satisfactory statistical evidence for generality. She suggested, however, that greater generality might have been obtained if each of the experimental tasks had offered an equally intense threat of failure to the subject. Gardner, using a somewhat different experimental set-up, obtained correlations ranging from .38 to .70 and concluded that there was a fair degree of generality between the aspiration scores obtained on tasks performed within the same test-in-a-psychological-laboratory frame of reference. Since Gould also worked within this laboratory framework, the divergent results of the two studies cannot be explained entirely on this ground.

It is suggested here that the differences in the results of Gould and Gardner may be explained in terms of certain differences in the procedures they employed. The differences that appear to be significant are:

1. Differences in the degree of similarity of the scale values in terms of which performance scores for the several tasks were reported to the subjects.
2. Differences in the degree of similarity of the shapes of the learning curves formed by the performance scores reported to the subjects.
3. Differences in the degree of similarity of the subject's motivation on the several tasks.

The present experiments were designed to test the hypothesis that the more similar the experimental situations in terms of these three factors, the greater will be the degree of generality of the levels of aspiration for different tasks. In Experiment I the degree of similarity of the performance score scales and the degree of similarity of

the shapes of the learning curves have been varied. In Experiment II the degree of similarity of the motivation of the subject on the several tasks has been varied.

Method

The general procedure of these experiments is similar to that of other recent studies of aspiration level. The subject was given 22 successive trials on each of several tasks. At the end of each trial he was told his performance score and was asked to state his goal for the following trial. The specific instructions were:

> Now I want you to tell me what score you are going to try to make on your next trial; that is, I want you to tell me what your goal is for your next trial.

If the subject asked if he were to estimate his performance on the next trial, the instructions were repeated, emphasizing that what was desired was a statement of the goal, not a judgment of future performance.

A prearranged series of false performance scores was reported to the subject on each task. The scores reported to any one group of subjects were the same for trials 2 to 21 but were different on trials 1 and 22. The first and last scores were varied so that, if the subjects later compared scores, they would not discover that the same scores had been reported to all. Deviations from the prearranged series of scores were made only when the subject's performance time on a trial differed greatly from the prearranged score. This variation was occasionally necessary to prevent the subject's becoming aware that false scores were being reported. Since falsification of score is easier with time scores than with accuracy or power scores, time scores were used throughout.

Five tasks were used. These were digit-symbol substitution, letter-code substitution, mental multiplication, addition, and card-sorting. The digit-symbol substitution task was a modification of the digit-symbol test used by Gardner (**6**). Each trial consisted of five five-place numbers. On each trial in the letter-code task, the subject was required to translate five five-letter words into the Civil War code given in the 1916 Stanford-Binet. In both of these tasks the codes were before the subjects at all times. In the multiplication task the subject solved mentally seven two-place problems on each trial. Before beginning this task the subject was told the easiest way of solving the problems in order to reduce the variability of his performance. The addition task consisted of problems selected from those prepared by Gould (**8**). Fifteen problems consisting of four one-place numbers were performed on each trial. On both of the arithmetic tasks the subject was to indicate which of two given answers was the correct one; in the multiplication problems, the correct and incorrect answers differed only in their middle terms. On the first few trials on these two tasks the subjects were told when they had made an error and were asked to correct it. Later, errors were ignored unless it appeared that the subject was becoming careless. At the beginning of each of the above four tasks the subject was given 22 slips of paper; each slip contained the material for one trial. The fifth task consisted of sorting fifty cards (10 of each of 5 designs) according to the technique described by Husband and Miles (**11**). The cards were sorted onto a large sheet of glass placed directly in front of the subject; on the reverse side of the glass was pasted one of each of the five kinds of cards. Errors were called as soon as made and had to be corrected before continuing. Since, with the four other tasks, the subject knew when he was approaching the last trials, the subject was told in the card-sorting task when he had completed all but the last two trials. This gave him equal opportunity to exhibit the end-spurt on all of the tasks. Each of the five tasks required about half an hour to complete.

The subjects of these experiments were 120 Yale undergraduates and 34 high school seniors who were applying for Yale scholarships. Each subject reported twice, performing two tasks during the first session and three tasks during the second session. An interval of from two to three weeks separated the two experimental sessions. The subjects were paid for their services.

The data of the experiments consist of the medians [1] of the 20 discrepancy scores obtained

[1] The median D-score was used rather than the D-score because of the fact that the occurrence of one or two unusually large D-scores carries a disproportionate weight in determining the average D-score. Since most of these large scores occurred during the first few trials on the first task performed during the first session, they were considered less typical than later responses.

from each subject on each task. The discrepancy score is the difference between a subject's reported performance score on a given trial and the goal he states for the succeeding trial. The performance scores actually used were those of trials 2 to 21; the aspiration scores, those of trials 3 to 22. Product-moment correlations between the median D-scores (discrepancy scores) obtained on the different tasks indicate the degree of correspondence between the subjects' levels of aspiration under the different experimental conditions. Because of the small number of cases involved, the reliability of the difference between these correlations was determined by Fisher's *z*-method (3).[2]

Experiment I

Procedure

Experiment I tests the effect of performance score similarity on the generality of level of aspiration. Performance score similarity was varied in two ways: (*a*) by varying the artificial performance score scale (*i.e.*, the possible range of the performance scores and the size of the interval between any two adjacent scores) in terms of which a subject's performance was reported to him, and (*b*) by varying the shapes of the learning curves formed by the prearranged, false performance scores. That part of the experiment dealing with performance score scale similarity will be treated as *Part A*, that part dealing with the similarity of the shapes of the prearranged learning curves as *Part B*, and that part dealing with the simultaneous variation of curve and scale as *Part C*.

In *Part A* two groups of 60 Yale undergraduates each were employed. Both groups of subjects performed digit-symbol substitution and mental multiplication in that order at the first session. One group of subjects (Group A in Table I) was given the same artificial performance score scale on these two tasks, half the subjects being given Scale I and the other half Scale II. The other group of subjects (Group B in Table I) was given different scales on each task, half the subjects being given Scale I first and the other half Scale II first. The scales used will be described later. Both groups of subjects were given the same prearranged learning curve (Curve I in Fig. 1) on both tasks. The absolute level of the learning curve was varied a few points for the different tasks to avoid reporting identical performance scores on the tasks. The degree of generality of the level of aspiration was measured by correlating the discrepancy scores obtained on these two tasks.

The two artificial performance score scales used consisted of thirty step-intervals each. The scores in Scale I ranged from a minimum of 50 to a maximum of 200 by step-intervals of five; a score of 200 was better than a score of 50. The scores in Scale II ranged from a minimum of 50 to a maximum of 20 by step-intervals of one; in this scale a score of 20 was better than a score of 50. When Scale I was used the subject was instructed as follows after the first trial on a task:

> After each trial I am going to tell you what score you made, but instead of reporting your score in terms of the number of seconds it took you, I am going to report it in terms of a scale we use around here. This scale goes from 50 to 200—50 being low, 200 high—by steps of five so that all the scores I tell you will be multiples of five like 60, 65, 80, and so on. Since 50 is low and 200 is high, as your speed increases, that is, as your time decreases, the score I will tell you will increase. For example, 80 is a better score than 75 and 90 is a better score than 80.

The instructions for Scale II were given in similar form.

In *Part B*, to test the effect of learning curve similarity on generality, the shape of the learning curve was varied for different tasks while the performance score scale was held constant. Two groups of subjects, each consisting of 36 Yale undergraduates, performed letter-code substitution, addition, and card-sorting at the second experimental session. Scale II was used on all tasks. One group[3] of subjects (Group M in Table I) was given the same prearranged learning

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[2] Fisher's formula is $z = 1.513 \left(\log 10 \frac{1+r}{1-r} \right)$. $\sigma_z = \frac{1}{\sqrt{N-3}}$.

[3] All of the subject of Part B had served in Part A two to three weeks prior to their participation in Part B. The two groups in Part B were equated in terms of their experience in Part A.

TABLE I

EXPERIMENTAL CONDITIONS EMPLOYED AND COMPOSITION OF THE VARIOUS EXPERIMENTAL GROUPS

Part	Variable	Group	Tasks	Scale	Curve	Subjects	Previous Experience of Subjects
I-A	Scale	A-1	Digit-Symbol	I	I	30 college	
			Mult.	I	I		
		A-2	Digit-Symbol	II	I	30 college	
			Mult.	II	I		
		B-1	Digit-Symbol	I	I	30 college	
			Mult.	II	I		
		B-2	Digit-Symbol	II	I	30 college	
			Mult.	I	I		
I-B	Curve	M	Addition	II	II	36 college	15 in A-1, 13 in B-1, 8 in B-2
			Card-Sorting	II	II		
			Letter-Code	II	II		
		N	Addition	II	IV	36 college	14 in A-1, 15 in B-1, 7 in B-2
			Card-Sorting	II	II		
			Letter-Code	II	III		
I-C	Curve and Scale	X	Digit-Symbol	I	I	29 college	29 from A-1; of these, 15 in M, 14 in N
			Mult.	I	I		
			Addition	II	II, IV		
			Card-Sorting	II	II		
			Letter-Code	II	II, III		
		Y	Digit-Symbol	II	I	29 college	29 from A-2
			Mult.	II	I		
			Addition	II	I		
			Card-Sorting	II	I		
			Letter-Code	II	I		
II	Motivation	X					These are the subjects of Group X above.
		Z	As X above	As X	As X	34 high school	34 as A-1 above; of these, 17 as M, 17 as N

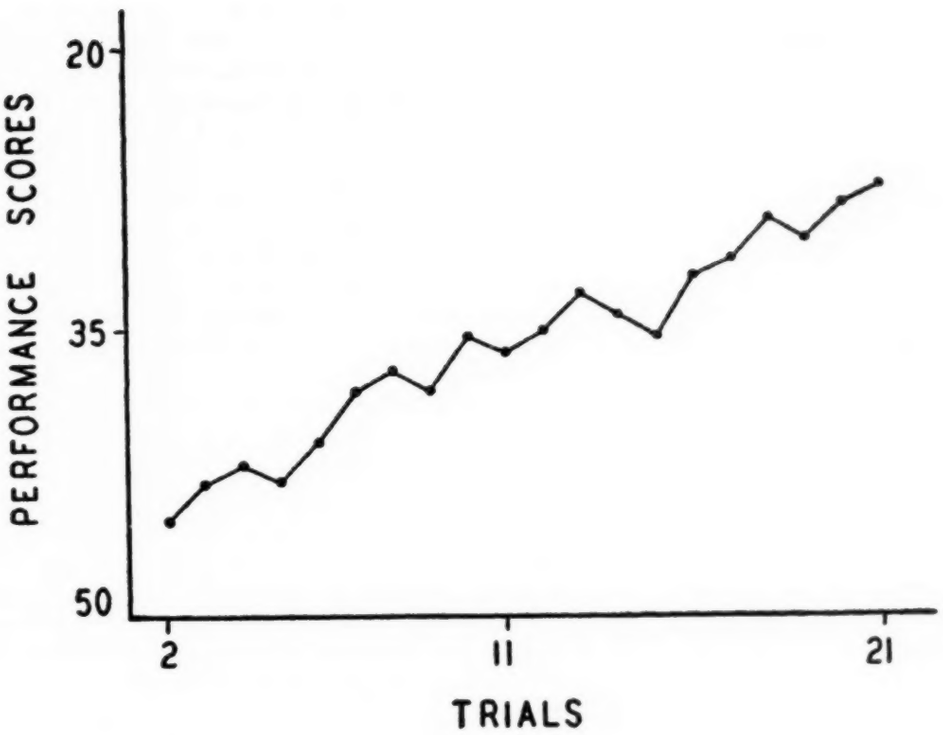

FIG. 1. The pre-arranged learning curve used in Experiment I, Part A. The performance scores are in terms of Scale II.

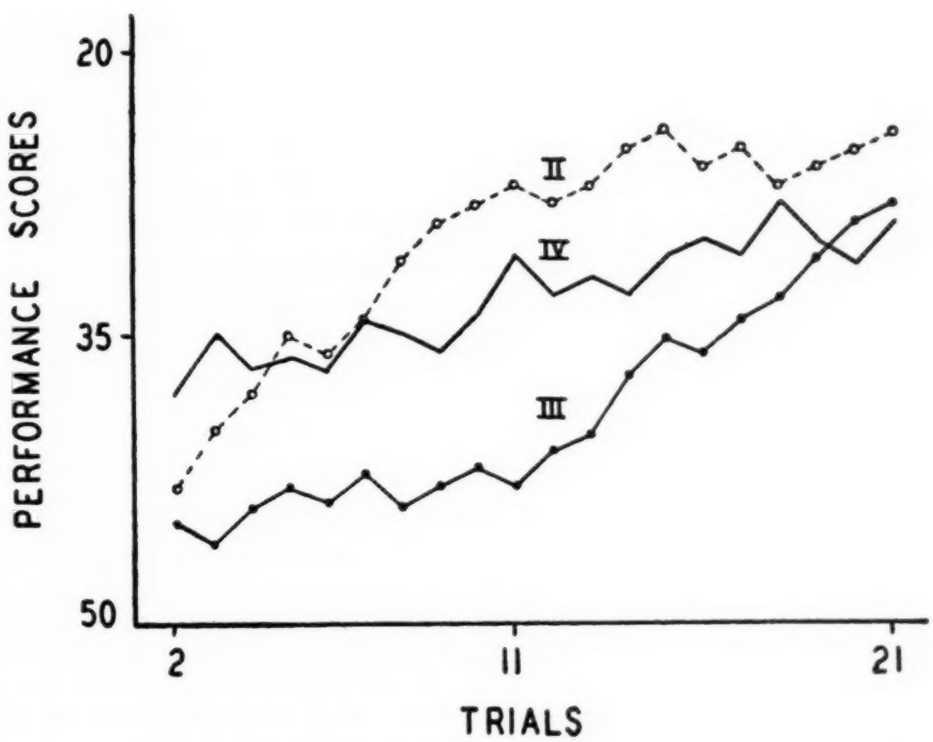

FIG. 2. The pre-arranged learning curves used in Experiment I, Part B. The performance scores are in terms of Scale II.

curve on all three tasks. The other group of subjects (Group N in Table I) was given a different prearranged learning curve on each of the three tasks. Figure 2 shows the shapes of the learning curves that were used. Curve II was used on all tasks with the first group of subjects, the absolute level of the curve varying for the different tasks. With the second group of subjects, Curves II, III, and IV were used on card-sorting, letter-code substitution, and addition, respectively. The order in which the three tasks were presented was systematically varied among the subjects of both groups. The correlation technique was again used to measure the effect of the shape of the learning curve on the generality of the level of aspiration.

The purpose of *Part C* was to compare the degree of generality in the level of aspiration obtained when performance score scale and learning curve shape were varied simultaneously, that is, when the experimental conditions approximated either those of Gould or those of Gardner. Accordingly, the degree of generality shown by a group of subjects who had received differently shaped prearranged learning curves and different performance score scales on the various tasks was compared with the degree of generality exhibited by a group of subjects who had been given the same prearranged learning curve and the same performance score scale on all of the tasks. Twenty-nine Yale undergraduates were used in each group[4] and each subject reported twice. One group (Group X in Table I) performed digit-symbol substitution and mental multiplication on Day I using Scale I and Curve I. On Day II they performed letter-code substitution, addition, and card-sorting with Scale II and Curves II, III, and IV. Hence the scales and curves used on Day II were always different from the scales and curves used on Day I. These conditions were similar to those of Gould. Another group of subjects (Group Y in Table I) performed the same tasks in the same order as Group X but with these subjects Scale II and Curve I were presented on all five tasks so that the scale and curve used on Day II were the same as the scale and curve used on Day I. These conditions were similar to those used by Gardner. The correlations between the D-scores obtained on tasks performed on different days by the two groups of subjects were compared.

Results

Table II presents the various correlations between the D-scores for the several tasks and the appropriate measures for the significance of differences between them.[5] In Part A are given the correlations between the D-scores when the scales used on two tasks were the same (Group A) and when they were different (Group B); these are .87 and .67 respectively. The difference between these coefficients is statistically reliable as shown by a critical ratio of 3.6 computed according to Fisher's *z*-method. These results demonstrate that the greater the similarity of the performance score scales, the greater the generality of the level of aspiration.

Table II, Part B, gives the correlations between the D-scores obtained on three tasks when the similarity of the shapes of the prearranged learning curves was varied. The correlations between the D-scores obtained on the three pairs of tasks when the same prearranged curve is used on all (Group M) and when differently shaped curves are used on each (Group N) are, respectively, .86 and .80 for

[4] In Part C part of the data obtained in Parts A and B were analyzed further. The subjects of Group X were the subjects of A-1 in Part A. It will be recalled that half of these subjects served in Group M, half in Group N in Part B. The subjects of Group Y were the subjects of Group A-2 in Part A; none of these subjects had served in Part B.

[5] As in other aspiration studies, the aspiration scores were found to be highly reliable. The corrected odd-even correlations between the mean D-scores ranged from .93 to .99 for all of the tasks with every group of subjects.

addition and card-sorting, .81 and .74 for letter-code substitution and addition, and .75 and .77 for letter-code substitution and card-sorting. Although in two of the three comparisons the correlations are slightly greater when the curves are the same on all the tasks than when they are different on all the tasks, these differences are not statistically significant. This suggests that similarity of learning curve shape does not affect the generality of the level of aspiration.

It will be noted, however, that, although the forms of the three learning curves varied, all were alike in that they allowed a certain

TABLE II

EFFECT OF VARYING THE DEGREE OF SIMILARITY OF THE PERFORMANCE SCORE SCALE AND THE LEARNING CURVE SHAPE ON THE GENERALITY OF THE LEVEL OF ASPIRATION IN EXPERIMENT I AS MEASURED BY CORRELATING THE MEDIAN D-SCORES

Pairs of Tasks	Group	Pearson Correlation	C.R. Diff.	Chances in 100
Part A. Effect of Varying Performance Score Scale Similarity				
Digit-Symbol, Mult.....	A	.87±.02		
Digit-Symbol, Mult.....	B	.67±.06	3.6	100
Part B. Effect of Varying Similarity of Learning Curve Shape				
Trials 2–21				
Code, Cards.....	M	.75±.05		
Code, Cards.....	N	.77±.05	0.2	58
Code, Addition.....	M	.81±.04		
Code, Addition.....	N	.74±.05	0.8	79
Addition, Cards.....	M	.86±.03		
Addition, Cards.....	N	.80±.04	1.0	84
Trials 2–11				
Code, Cards.....	M	.95±.01		
Code, Cards.....	N	.76±.05	4.6	100
Code, Addition.....	M	.83±.03		
Code, Addition.....	N	.61±.07	2.2	99
Addition, Cards.....	M	.82±.04		
Addition, Cards.....	N	.85±.03	0.5	69
Trials 12–21				
Code, Cards.....	M	.78±.04		
Code, Cards.....	N	.81±.04	0.4	65
Code, Addition.....	M	.66±.06		
Code, Addition.....	N	.78±.04	1.2	88
Addition, Cards.....	M	.74±.05		
Addition, Cards.....	N	.87±.03	1.8	96

TABLE II—*Continued*

Part C. Effect of Varying Similarity of Both Performance Score Scale and Learning Curve Shape

Digit-Symbol, Code...	X	.59±.08		
Digit-Symbol, Code...	Y	.93±.02	4.6	100
Digit-Symbol, Add....	X	.57±.08		
Digit-Symbol, Add....	Y	.82±.04	2.4	99
Digit-Symbol, Cards..	X	.35±.11		
Digit-Symbol, Cards..	Y	.79±.05	3.3	100
Mult., Code.....	X	.74±.06		
Mult., Code.....	Y	.87±.03	1.8	96
Mult., Addition.....	X	.64±.08		
Mult., Addition.....	Y	.93±.02	4.3	100
Mult., Cards.....	X	.61±.08		
Mult., Cards.....	Y	.85±.03	2.6	99

amount of improvement from beginning to end.[6] As may be seen from Fig. 2, the greatest difference in the amount of improvement allowed by the curves occurred during the first ten trials with Curves II (card-sorting) and III (letter-code substitution). If the median of the D-scores for each subject on the first ten trials on the two tasks on which Curves II and III were used are compared with the median of the D-scores for each subject on the first ten trials on the same two tasks when Curve II was used on both, we find reliable differences in the degree of generality as is indicated in Table II, Part B, Trials 2–11. The correlations between card-sorting and letter-code substitution for the group having the same curve on both tasks (Group M) and for the group having different curves on each task (Group N) are .95 and .76 respectively (C.R. = 4.6). However, if the median D-scores for the last ten trials on the same tasks are compared in similar fashion, this difference does not appear although, superficially, the second halves are as different from each other as the first halves. The correlations between the median D-scores obtained on the last ten trials are .78 for Group M and .81 for Group N as may be seen in Table II, Part B, Trials 12–21.

Table II, Part C, gives the correlations obtained between D-scores for tasks performed on different days when the curve and the

[6] To have used curves permitting very different amounts of improvement would have required that some of the curves give considerable failure stimulation. Such a situation was avoided since it was felt that continuous failure stimulation would increase the motivational level of the subject in that particular task and that this would carry over to other tasks performed during the same session. It was desired that the level of motivation of these subjects towards a particular task be determined primarily by the subjects' attitudes towards the tasks rather than by the experimental procedure.

scale were the same on Day II as on Day I (Group Y) and when the curves and scales were different on Day II than on Day I (Group X). Although there is considerable variability both in the actual size of the correlations and in the degree of difference between them, it will be seen that the correlations for Group Y are, without exception, greater than the correlations for Group X. Since the correlations for Group X range from .35 to .74 while those for Group Y range from .79 to .93, there is no overlapping between the correlations for the two groups. Four of the six correlations are reliably greater (C.R. above 2.5) for the group in which the curve and scale are the same on both days than for the group in which the scales and curves are different on both days. These findings suggest that the conflicting results of Gould and Gardner regarding the degree to which the level of aspiration is generalized are at least in part a function of the differences in their experimental procedures relative to the degree of similarity of the learning curves and performance score scales employed.

Experiment II

Procedure

Experiment II tested the effect on generality of the level of aspiration of the similarity of the subject's motivation from task to task. Motivation was varied by means of special instructions and by means of offering rewards. The aspiration levels of two groups of subjects were compared on the five different tasks. The first (non-reward) group [7] of subjects (Group X in Table I) was made up of 29 Yale undergraduates. The second (reward) group of subjects (Group Z in Table I) was made up of 34 high school seniors who were applying for Yale scholarships. So far as possible the social and educational backgrounds of the two groups were equated.

The Yale students, many of whom were local boys with Yale scholarships, reported individually from the Yale Personnel Bureau. Most of them had had previous experience as psychological subjects and regarded the experimental situation as a means of earning money. For most of these subjects the situation did not have high prestige value. On the other hand, only two of the high school students had been psychological subjects prior to this experiment and none of them had had courses in psychology. Since all of them desired to attend Yale and were, at the time the experiment was being conducted, preparing for achievement tests and college boards, the association with the Yale Psychology Department probably did have prestige value for them. The prospective high school subjects were sent a form letter in which they were told that the Psychology Department of Yale University was sponsoring a series of psychological tests on superior individuals. Inasmuch as they were scholarship applicants, they were considered to be definitely superior individuals and were, accordingly, requested to participate in the testing program. The students who volunteered their services met first as a group in one of the college lecture halls with the knowledge that all other persons in the group were also scholarship applicants. At this group meeting they were told that they were going to be given a series of psychological tests in order to determine their intelligence and their skill on a series of tests of learning ability. They were also told that, since superior individuals seldom work at top capacity, a $10, a $5, a $3, and four $1 prizes were being offered to encourage them to work at their highest level. The prizes would be given on the basis of the initial skill and the amount of improvement shown in the several tests. The prizes would be announced and presented at a second group meeting at which time they would also be paid for their services. During the first group meeting the subjects were given Form D of the Otis Higher Intelligence

[7] It will be noted that this is the same Group X which served in Part C of Experiment I.

Examination, the MacQuarrie Mechanical Aptitude Test, and the Bernreuter Personality Inventory in order to increase the reality of the experimental situation as a testing program.

Both groups of subjects reported for two sessions which were separated by a two-week interval. During the first session they performed digit-symbol substitution and mental multiplication in that order. During the second session they performed digit-symbol substitution, addition, and card-sorting, the order in which the tasks were done being systematically varied. These tasks were always referred to as 'tests' with the high school subjects and as 'the next thing to do' with the college subjects. For both groups Scale I was used during the first session, Scale II during the second. During the first session Curve I was used on both tasks. During the second session half the subjects received the same shaped curve on all tasks (Curve II) and half received a differently shaped curve on each task (Curves II, III, and IV).[8] In every case, however, the shape of the learning curve given during the second session was different from the shape of the curve given during the first session.

Results

Table III gives the intra-day and inter-day correlations between the D-scores obtained on the tasks performed by the non-reward group (Group X) and the reward group (Group Z).

TABLE III

EFFECT OF VARYING THE DEGREE OF SIMILARITY OF THE MOTIVATIONAL VALUE OF PERFORMANCE SCORES ON GENERALITY IN THE LEVEL OF ASPIRATION. PRODUCT-MOMENT CORRELATIONS BETWEEN THE MEDIAN D-SCORES OBTAINED ON TASKS PERFORMED IN EXP. II

Pairs of Tasks	Group X	Group Z	C.R. Diff.	Chances in 100
Intra-Day Correlations				
Day I				
Digit-Symbol, Mult.	.84±.04	.93±.02	2.6	99
Day II				
Code, Addition	.82±.04	.71±.06	1.6	94
Code, Cards	.77±.05	.80±.04	0.4	65
Addition, Cards	.85±.04	.77±.05	1.0	84
Inter-Day Correlations				
Digit-Symbol, Code	.59±.08	.47±.09	0.8	79
Digit-Symbol, Add.	.57±.08	.83±.04	2.6	99
Digit-Symbol, Cards	.35±.11	.51±.09	1.0	84
Mult., Code	.74±.06	.65±.07	0.8	79
Mult., Addition	.64±.07	.81±.04	1.8	96
Mult., Cards	.61±.08	.65±.07	0.3	62

The results are not unequivocal. Those obtained on Day I favor the hypothesis that the similarity of the motivation of a subject for the various tasks increases the similarity of his aspiration levels on those tasks. The correlations between the D-scores on the two tasks performed on Day I are .93 for the reward group (Group Z) and .84

[8] This procedure was used because of the fact that the aspiration scores of Group Z were to be compared with those of Group X. Since this was the procedure used with Group X it was necessarily the procedure used with Group Z also. Group Z was compared with Group X rather than with Group Y because the conditions of Group X produced less generality than those of Group Y.

for the non-reward group (Group X). The critical ratio of the difference is 2.6 sigma. On Day II, however, this difference disappears. The coefficients for Group Z are either lower than or practically the same as those for Group X. If the inter-day correlations between the D-scores for the two groups are compared, it is seen that the degree of generality shown by the reward group is greater than the degree of generality of the non-reward group in four of the six comparisons. In only one case, however, is this difference reliable.

Discussion

The results of this investigation support the view that generality in the level of aspiration is in part a function of objective similarities in the situations within which the aspirations are set. That is, the similarity of an individual's aspiration level in two tasks is a function not only of his personality structure, but also of the objective similarity of the two tasks themselves. In other words, it is likely that the objective similarity of two situations tends to increase the similarity of the subject's expectations of success or failure within those situations. Chapman and Volkmann (**2**) have shown that the standard most frequently used by a subject in evaluating his achievement is his knowledge of his own past performance in the same or similar situations. The more similar the subject's evaluation of his performance on two tasks, then, the more similar, all other things being equal, will be the threats of failure offered him by the two tasks.

Reporting performance scores in terms of the same performance score scales gives greater generality in the level of aspiration than reporting scores in terms of different scales. This result probably occurs because the subject more readily perceives the similarity of his achievement on two tasks when the performance scores are reported in terms of the same scale than when they are reported in terms of different scales.

It will be recalled that, when the shape of the learning curve was varied significant differences in the degree of generality of the aspiration response were not obtained when the D-scores compared were based on the curves as wholes. Differences became significant only when the D-scores compared were those based on the first halves of definitely unlike curves. These results become intelligible if we assume that learning curves do not represent sequences of individual and unrelated scores but, rather, total stimulus situations representing the amount and rate of improvement. From this point of view, the use of non-identical curves would be expected to decrease generality only if the contours of the curves were different enough to provide the subject with different interpretations concerning the amount and rate of his improvement.

It is possible that differences in the correlations between D-scores based on the total trials for a task were not significant because the curves used did not satisfy the above criterion. From Figs. 1 and 2 it may be seen that all of the curves allowed about the same amount of total improvement and that with all of the curves trials on which improvement occurred predominated. Thus both the identical and the non-identical curves provided considerable success stimulation.

Reliable differences in generality were obtained when D-scores based on the first halves of definitely unlike curves (Curves II and III) were compared with the first halves of like curves because these unlike portions of the curves did allow different amounts of improvement and, consequently, different degrees of success stimulation. From Fig. 2 it may be seen that the first half of Curve III permitted almost no improvement; the scores for these first ten trials were all above 40 in a performance score scale which ranged from a minimum of 50 to a maximum of 20. With Curve II, on the other hand, improvement was rapid and steady during the first ten trials. The subjects' remarks indicated that many of them experienced failure with Curve III and success with Curve II. Furthermore, many of these subjects reported at the end of the experiment that they had done least well on and had liked least the letter-code task and that they had done well on and had liked best the card-sorting task. It would appear, then, that one group of subjects received success stimulation on both tasks while the other group received success stimulation on one and failure stimulation on the other. As might be expected, the first group of subjects showed greater generality than the second.

That success and failure rather than the sequence of scores as such is the determining factor is indicated by the fact that the degree of generality is not significantly greater for the last ten trials when the same curve (Curve II) is used on both tasks than when different curves (Curves II and III) are used on the tasks although during the last ten trials the two sequences of scores are as different as they are in the first ten trials. The lack of improvement during the last ten trials with Curve II would probably not provide failure stimulation since the performance scores had already approached the best score possible. With Curve III improvement was rapid and steady during the last ten trials. Hence neither group of subjects received success stimulation on one task and failure stimulation on the other.

The hypothesis that similarity in the perceived goodness of performance on several tasks tends to increase the degree of generality between the aspiration scores stated on those tasks, is supported by Sears' (13) finding that the aspiration levels of children on reading and arithmetic tests are more similar if the children have experienced

success or failure on both than if they have experienced success on one and failure on the other.

Experiment II was designed to test the effect on the generality of the level of aspiration of varying the degree of similarity of the subject's motivation on the different tasks. This was done by modifying the instructions so as to elicit more similar attitudes towards all the tasks from the rewarded subjects than from the non-rewarded subjects. A subject in the non-reward group might regard a task, depending on his individual attitudes, as a test, a bore, a job, or a game, and his evaluation of his performance would be conditioned by the relative importance of the particular task to him. But a subject in the reward group was encouraged to regard all the tasks in a similar manner since he was told that the tasks were all tests of learning ability. In addition, since the prizes were awarded on the basis of a subject's performance on all of the tasks, it was necessary for him, in order to demonstrate superiority, to be good on all rather than on any one task. By thus constructing the situation for the reward group so that essentially the same level of achievement was prescribed for each task, a subject's feelings of success and failure, given the same objective achievement level, would also tend to be similar from task to task if we assume, as seems likely, that feelings of success and failure are dependent not upon absolute degree of accomplishment but upon accomplishment in relation to a given goal. If the above assumption is correct, increasing the similarity of a subject's evaluation of his performance on different tasks should produce greater generality in his levels of aspiration for the tasks.

It was found that the reward group showed greater generality than the non-reward group for the tasks done on Day I only. The fact that the reward group did not show greater generality on Day II also may indicate, not that the hypothesis is incorrect, but that the motivation established by the group meeting did not persist over the two-week period intervening between the two experimental sessions. That it did not persist is not surprising when one considers three facts: (1) An average of about three weeks elapsed between the first group meeting and the second experimental session. (2) All subjects took the College Board Examinations on the day that separated the last of the first sessions and the first of the second sessions. The invariable reaction of the subjects on returning to the laboratory was that the Psychology Department tests were so much easier than the College Board tests that, in comparison, they were mere play. (3) The learning curve (Curve I) used on Day I allowed steady and rapid improvement so that a good score was obtained without much effort. This would tend to reduce the seriousness of the test situation for

the subject if, as appears plausible, a situation is accepted as a personal test only when it involves potential failure.

The results discussed above indicate that the similarity of a subject's levels of aspiration in two situations depends upon the similarity of the two situations to the individual as well as upon his personality organization. It should be noted, moreover, that a subject might possess an individual trait, as that term is used by Allport (1), of such a nature that all tasks with which he was faced would have equivalence as sources of potential failure regardless of the degree of their objective similarity. Given an adequate sampling of the population, however, differences in the degree of generality of the level of aspiration reported by different investigators may be explained, at least in part, as a function of differences in the degree of similarity of the task situations employed by the respective experimenters.

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DEGREE OF EFFORT: III. RELATIONSHIP TO THE LEVEL OF ASPIRATION

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The level of aspiration defined in objective terms "represents the level of future performance in a familiar task which an individual explicitly undertakes to reach" (Frank, 1). The difference between the score which an individual expects to make as compared with the score which he has actually made in a task is the quantitative measure of the operation of this characteristic. The greater the predicted score from the actual score the higher is the individual's level of aspiration. The degree of effort, on the other hand, deals with the quality of methods which the individual uses to obtain the end results in a task (**5, 6**), rather than with an individual's prediction of the end results in future tasks. Since an individual who is expending a greater degree of effort is using the more difficult methods of completing a task, it might be supposed that if there is any relationship between the degree of effort and the level of aspiration, such an individual would also set for himself a higher goal in future performance, than the individual who is satisfied to reach the end results in a task by inferior methods. On this basis there should be a direct relationship between the degree of effort expended and the level of aspiration. As will be seen, however, exactly the opposite results were obtained, which means in effect that a common factor is responsible for the results, but, contrary to expectation, the individual who is certain that he can better his past score uses inferior methods to complete tasks.

METHODS

Four tasks, tapping, substitution, stringing beads, and free word association, were used to obtain a measure of the level of aspiration. On the tapping test the individual was instructed to place two dots with a pencil in each square on a page ruled into 10 by 15 squares. The substitution test was similar to test 4 of the Army Beta, Form O, in which the individual is required to place different symbols under their appropriate numbers; a card with different symbols was used for each trial. On the third test the subject was instructed to string beads, alternating between a blue and a yellow bead. On the final test the subject was told to name different words. The time allowed for each trial for the four tasks in the above order was: 15, 60, 60, and 30 seconds. Speed of performance was emphasized on each test.

Four trials were given on each one of the tasks. After each trial the individual was informed of his score and was asked to state the score which he expected to make on the next trial. Thus for each task the individual made 3 predictions, or a total of 12 predictions on the four tasks. In making the predictions the individual could either give a numerical score or simply state

that he expected to do better, same, or less; the level of aspiration being determined by his statement as to whether he expected to increase, to decrease, or to obtain the same score in relation to the score which he made on the trial just preceding the prediction. The subjects were tested individually without knowledge of the scores made by other individuals.

As in the preceding study 40 subjects (16 males, and 24 females; average age 38.4 years, range 12 to 58 years) were selected to compose the four groups of 10 individuals in each group expending different degrees of effort as determined by the open and blocked runway tests. Again to make the selection five trials were administered on the open runway, and four trials on the blocked runway tests. The individuals were rated in the degree of effort expended by the number of tools they failed to use on the open runway test, but used when the runway was blocked. In the graphs this score is expressed as the difference between the number of tools used on the open runway and the number used on the blocked runway tests. If the individual used the same tools on the open and blocked runway tests he expended a maximum degree of effort; if he failed to use 1, 2, or 3 tools on the open runway test, but used these tools when the runway was blocked, he expended progressively less effort. Subjects who make no use of the tools on either test are not included in the study since these methods of completing the task are not available to them.

Because of the nature of the results as the experiment progressed, the answers of a few subjects, as the experiment was being completed, were obtained to the question, "Do you believe you have more confidence, or the same confidence, or less confidence in yourself than the average individual?"

Results

Quantitative Data.—Figure 1 shows the average number of times that the individuals expending the different degrees of effort predicted

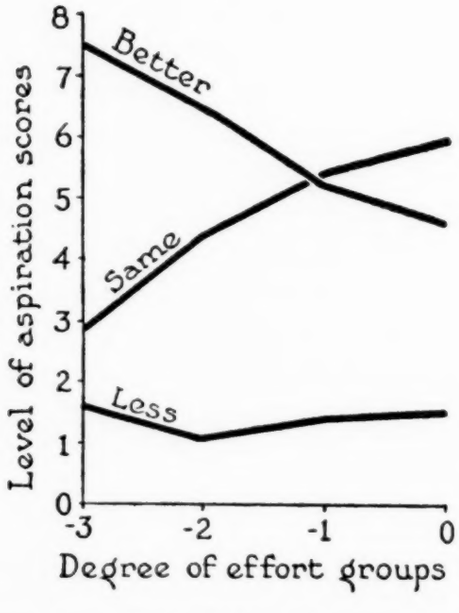

Fig. 1. The average number of times that the four groups of subjects expending an increasing degree of effort predicted that their scores would be better, same, or less than their preceding scores on the four tasks used to measure the level of aspiration. The − 3 group expended the least and the 0 group expended the most effort.

that their scores would be better, same, or less than their preceding score on the four tasks. It is seen that as the degree of effort which the groups expend increases the frequency with which the groups predict that their scores will be superior to their preceding score decreases, and the frequency with which they expect their scores to

remain the same increases. These differences between the groups are significant. All of the groups, however, predict with the same frequency that they will make an inferior score on future performances.

Some notion of the results of individual cases can be obtained from the fact that the number of subjects who predicted with a greater frequency out of the 12 predictions that their scores would increase, rather than decrease or remain the same, in the four groups expending an increasing amount of effort were: 8, 7, 3, and 3.

In Fig. 2 are plotted the results from each of the four tasks using only the average number of times that the individuals expected to better their scores. It is seen that the results of all four of the tasks

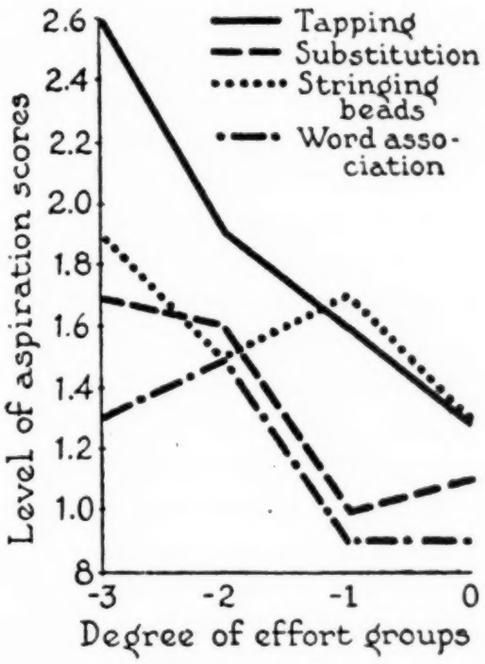

FIG. 2. The average number of times that the four groups of subjects expending an increasing degree of effort (— 3 means a minimum and 0 a maximum degree of effort) predicted that their scores would increase from their preceding scores on the tapping, substitution, stringing beads, and free word association tasks used to measure the level of aspiration.

showed the trend that the level of aspiration is related inversely to the degree of effort. The responses of the individuals as to whether they expected to make identical or inferior scores on each of the four tests also followed the same trend as the scores obtained from the total of the four tests.

Verbal Reports.—Only two of the subjects who exerted the greatest degree of effort (used the same tools on the open and blocked runway tests) and who had a low level of aspiration (predicted a total of only three times out of 24 predictions that their scores would be better) were questioned as to their 'confidence' in themselves. One of them stated, "I feel that I am not able to mix with crowds because I have

had less opportunity; it makes me feel inferior that I cannot keep up with them," and the other said, "I have always felt inferior." Of two individuals who were questioned who expended a minimum degree of effort (failed to use all three tools on the open runway test) and who had a high level of aspiration (predicted a total of 18 times out of the 24 predictions that their scores would be better), one stated, "I have average confidence," and the other, "I have a great deal of confidence."

Among the individuals who were questioned there were two who expended the greatest degree of effort, but who, contrary to the general trend, had a high level of aspiration (predicted a total of 19 times out of the 24 that their scores would be better). One of them stated, "I wouldn't be human if I didn't think I was better, but due to the knocks I have had in the last 8 or 10 years you lose your confidence. Prior to that time I made a slip (referring to a quarrel with his supervisor in a poker game) and landed where I am. If I hadn't made that change I would have been on equal footing with everyone. Since that time things have been going from bad to worse." The other individual said, "I am getting worse that way all the time. I do interior decorating. I tell people that I am not so good, but I do a pretty good job." These replies are reported at length because they suggest that there is a definite incompatibility between the individual's rating of himself and his actual achievement. In the one case there is a feeling of superiority in the face of failure; in the second case a feeling of inferiority, although the individual is comparatively successful.

A few of the individuals who obtained scores between the extremes in the degree of effort classification, *i.e.*, those individuals who failed to use one or two tools on the open runway test, were also questioned about their 'confidence' in themselves. Their responses are not reported since, as can be expected of individuals who represent the median in a distribution, no general tendencies were apparent in their replies.

Discussion

Two hypotheses can be advanced to explain the fact that the individual who expends the greater degree of effort has a lower level of aspiration than the individual who is exerting less effort. First of all, such a relationship might show a realistic attitude in making the predictions on the part of the individual, since if he is exerting a maximum degree of effort to produce the best results there is little reason to expect that such results can be better on subsequent trials, whereas if one is exerting less effort there is more opportunity for improvement. If this relationship actually displays realistic think-

ing then the following relationships of the performance should be evident: (1) The actual scores made on these tasks (especially on the first one or two trials of the four trials of each task) should be higher for those individuals who expend the greatest degree of effort, for if this is true then the possibility of increasing the score is slight. (2) There should be a greater improvement in the actual scores of those individuals who expend the least effort, for if that condition obtains then the subjects have predicted their results correctly. Analysis of the data showed, however, that neither one of these conditions was true. As a matter of fact there was a tendency for the actual scores of the individuals expending less effort to be greater than that of individuals who expend more effort.[1]

The second alternative to explain the inverse relationship between the degree of effort and the level of aspiration is to assume that a similar behavior characteristic is responsible for the phenomena defined as the degree of effort and the level of aspiration. 'Confidence' in oneself might produce, for example, a high level of aspiration, but a tendency to be less meticulous in one's work resulting in the use of inferior methods in completing tasks. The individual who lacks 'confidence' would hesitate to predict that his scores will be bettered on future trials, and would be more likely to use the best methods possible in completing a task since he would have little personal assurance as to the quality of his work. The possibility that 'confidence' is the characteristic which accounts for the relationship between the level of aspiration and the degree of effort is suggested by the verbal reports of the individuals. Of the individuals who were questioned, those who expend a maximum degree of effort and who have a low level of aspiration report little 'confidence' in themselves, but those individuals who show the opposite relationship report an average or above average amount of 'confidence.'

The results of Sears (4) showing that academically unsuccessful children have a higher level of aspiration than academically successful children, might, in part, be reinterpreted in terms of the results obtained in this study. Of the two groups of children studied by Sears some reasons besides that of ability must account for success and failure in school, since the groups were homogeneous in general ability. If a successful child in school achieves this status because he expends a maximum degree of effort in using the more difficult

[1] On all of the four tasks which were used to measure the level of aspiration there was a gradual increase in the scores as the groups expended a diminishing degree of effort; although only the results on the substitution test were significant ($.05 > P < .01$). The explanation for this relationship is contained in the preceding studies. It was shown that if time is allowed to vary, the individuals who expend a greater degree of effort take more time to complete a task. If time is kept constant, as in this study, then one would expect that in the same time interval the individuals expending less effort would do a greater amount of work.

methods in his school tasks and at the same time has a low level of aspiration, and if the unsuccessful child expends a minimum degree of effort in his school work and has a high level of aspiration, the suggestion is warranted that some academically successful children have less 'confidence' in themselves than some unsuccessful children. In such children the presence of 'confidence' in varying degrees would account for the grades obtained in school and the level of aspiration scores.[2]

The general trend of the results shows an inverse relationship between the degree of effort and the level of aspiration. The individual whose scores do not follow this trend is the exception. From the verbal reports, it appears that the individuals whose scores do not follow the expected trend in the fact that they display both a high level of aspiration and a maximum degree of effort do not appraise themselves realistically in terms of their history of employment. Likewise, a few individuals with definite paranoic trends who have been thus far tested displayed a high level of aspiration and a maximum degree of effort. From these results the suggestion can be entertained that individuals who do not display the expected inverse relationship between the level of aspiration and the degree of effort show an incompatibility between the reality of performance in actual employment and their own judgment about themselves.

The conclusion that a high level of aspiration associated with a minimum degree of effort appears to be an expression of a different characteristic from a high level of aspiration when the degree of effort is maximum agrees with the observations made by many experimenters that similar scores on level of aspiration tests may be due to dissimilar causes. The lack of correlation between the level of aspiration scores and personality traits reported by Gardner (**2**), and Gould and Kaplan (**3**) can be expected if identical level of aspiration scores are an expression of different traits.

Summary

1. The levels of aspiration, using four tasks, were determined for four groups of subjects, with 10 subjects in each group, displaying an increasing degree of effort as determined by the open and blocked runway tests.

2. An increasing degree of effort is associated with a decreasing

[2] Using the criterion identical to that used in the present study to measure the level of aspiration, Sears reports that of five children who belonged to the group which predicted on two tasks that their scores would not improve from 11.29 to 13.86 times out of 20 predictions, three were academically successful and two failures, as compared with one successful and five academically unsuccessful children who belonged to the group that anticipated out of 20 predictions that their scores would fail to improve from 0.56 to 0.89 times.

number of predictions that the scores will improve, and with an increasing number of predictions that the scores will remain the same on the level of aspiration tasks.

3. The results lead to the conclusion that the level of aspiration is related inversely to the degree of effort. The characteristic responsible for this phenomenon might be similar to that which is commonly called 'confidence.'

4. The individuals whose scores do not display the expected inverse relationship between the degree of effort and the level of aspiration appear to be unable to evaluate their ability realistically. Such individuals report a feeling of superiority or inferiority which is unwarranted by their history of actual employment.

5. Since similar level of aspiration scores may be due to different causes, little correlation can be expected between such scores and personality traits.

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PULSE RATE RESPONSE OF ADOLESCENTS TO AUDITORY STIMULI *

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Introduction

In an extensive study of adolescence made at the Institute of Child Welfare (**12**), a series of physiological measurements were taken in order to derive quantitative estimates of individual differences in the pattern and extent of physiological responses in emotionally provocative situations. The present study represents an attempt to quantify changes in pulse rate following startling stimuli. Since the pulse records and the galvanometric records were obtained for the same subjects in the same situations, later reports will deal with an analysis of patterns of response, involving a consideration of both of these aspects of physiological reaction.

Although some investigators have reported cardiac slowing after sudden auditory stimuli (**15, 17**), the majority have reported that sudden startling sensory stimuli result in cardiac acceleration of considerable magnitude (**1, 2, 5, 8, 14**). In many of these studies the stimuli were of such intensity that appreciable motor reaction occurred: thus, the cardiac effects may well have been a combination of the startle effect itself plus the metabolic and cardiovascular effects of the attendant motor activity.

The present study reports the cardiac response to sudden auditory stimuli in a group of adolescent children. Although the sounds used were reported by the subjects as 'startling,' the amount of motor activity produced was negligible as observed at the experiment and shown in the records (see Fig. 6).

Experimental

Subjects.—Observations were recorded on 45 girls and 47 boys chosen from the Oakland Public School population primarily on the basis of the probability of their availability for study

* Grateful acknowledgment for statistical assistance in the preparation of this report is made to the Work Projects Administration (O.P. Nos. 665–08–3–30, Unit A-8 and 65–1–08–62, Unit A-8). Thanks are due the Oakland Public Schools for making subjects available for the Adolescent Study of the Institute of Child Welfare, of which this study is a part.

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over a period of six or seven years. The average age of the children was 14.00 years at the time the tests here reported were administered. The standard deviation of the distribution of ages was .48 year. Each child had been tested six times previously under similar basal physiological conditions, *i.e.*, all the tests were administered between 8 and 9 o'clock in the morning before the child had been given breakfast. Tests were given with the child lying supine in the experimental cabinet described by Jones (11).

Stimuli.—The sound stimuli consisted of the following: (1) a loud snap produced by releasing a flat spring one-half inch wide, which struck the outside of the thin plywood door of the experimental cabinet just beside the head of the subject; (2) a siren which was run for a 2-second period; (3) a tone of a frequency of 145 cycles; (4) a tone of 307 cycles; (5) an electric automobile horn; (6) a fire gong with a six-inch diameter bell; (7) a cap pistol shot; (8) the harmonic chord in A major. The musical tones were produced by a vacuum tube oscillator operating through a loud speaker. The position of each sound in the series was systematically rotated for each test in order to control the effect of position in series. Twenty seconds after the sound stimulus the child was asked to report his rating of the degree of startle which he experienced. The instructions were as follows: "Now you will hear a series of sounds. After each sound I will ask you to look at the chart in front of you and use it to tell me how startled or surprised you were by this sound. Please be sure not to say anything until I am ready and ask you for your rating." The rating of startle was made on a five-point scale as follows: 0 = no startle at all; 1 = slightly startled; 2 = moderately startled; 3 = very startled; 4 = extremely startled. The mean values for ratings of startle for each sound are shown in Table 1.

TABLE 1

MEAN STARTLE RATINGS FOR SOUND STIMULI

	N = 92 (47 Male + 45 Female)
	Mean Startle Rating *
Loud snap	2.43
Auto horn	2.79
Cap pistol	1.99
Siren	.96
Gong	1.29
Harmonic chord	.15
Tone f = 145 d. v.	.16
Tone f = 307 d. v.	1.07

* Rating scale for startle. 0 = no startle at all; 1 = slightly startled; 2 = moderately startled; 3 = very startled; 4 = extremely startled.

In analyzing the data, displacements of pulse rate were measured for the sound stimulus.

Pulse Rate Recording.—The pulse rate was recorded from a pneumatic cuff attached to the ankle of the subject. A pressure of 50 mm of mercury was maintained in the cuff and changes in volume which resulted from each heart beat were recorded photographically by using a metal bellows and light lever system for adequate magnification (16). (See Figs. 6 and 7 for sample section from record.)

Method of Counting Pulse Rate.—Estimates of pulse rate based on the duration of single beats would give the most reliable picture of fluctuations in pulse rate. However, the paper speed of our photo-kymograph of one-eighth of an inch per second made such determinations impracticable. Hence it was important to determine how long an interval could be used for estimating pulse rates, and still be adequately short for indicating changes in pulse rate after stimulation. A preliminary study was made to determine the maximal interval which could be used for counting pulse rates from the data at hand. Figure 1 presents comparative data for intervals of 1, 2, 3 and 5 seconds in the estimation of pulse rate response to the stimulus of an automobile horn. From these curves it may be seen that the displacements in pulse rate so apparent when the one-second interval is used, are greatly obscured when the same data are analyzed on the basis of a five-second interval. On the other hand, the two- and three-second

intervals appeared to be about equally adequate for these data since both showed measurable changes in the same direction as the curve using the one-second interval. The three-second interval was finally chosen for work because it seemed to allow greater accuracy in counting and required less clerical work than the two-second interval. Two independent readings were made for each pulse rate by counting to the nearest 0.2 the number of beats within the given three-second interval. In the majority of cases these readings agreed. If they did not, a third independent reading was made and the two similar readings, or the mean of the three (in case all three disagreed, which occurred rarely) was taken as the accepted count. These counts of the number of beats per three-second interval were then converted into rate-per-minute by multiplying by 20. If, for any interval, the record could not be read because of technical imperfections or movement of the subject the entire count for that stimulus was discarded. The total time interval over which the pulse was counted for each stimulus was six seconds preceding the administration of the stimulus and fifteen seconds following. The stimuli were presented at least twenty seconds apart. Table 3 shows that by the end of 15 seconds the pulse rate did not differ significantly from the pre-stimulus count.

The data have been treated in terms of deviations from the pre-stimulus rate for each stimulus rather than from a 'normal' or resting rate in order to show the immediate effects of the stimulus.

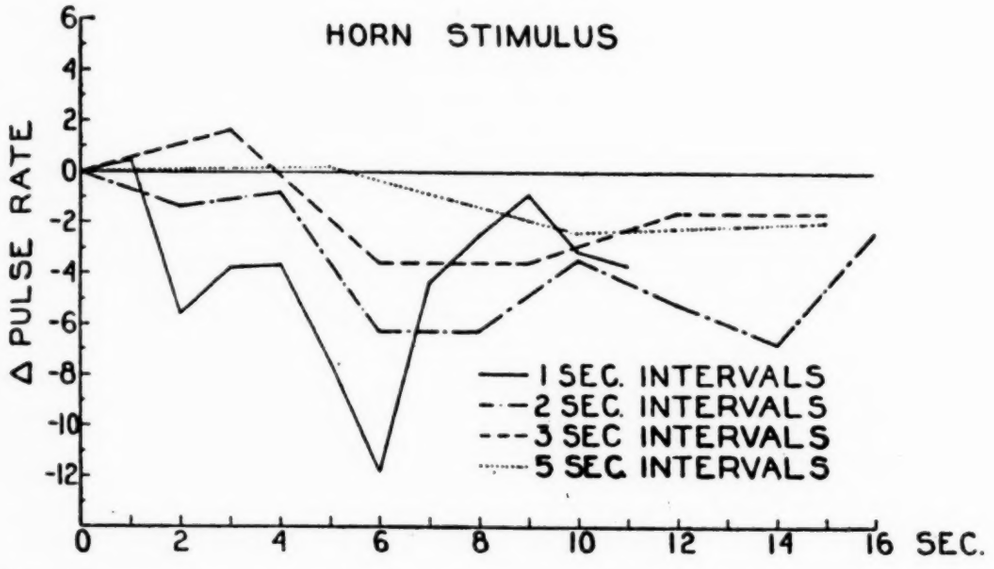

FIG. 1. Average pulse rate change in 11 adolescent boys following automobile horn stimulus. Change in rate is plotted as deviation from the average rate during the 6 seconds preceding the stimulus. The four curves illustrate the effect of the length of interval over which the count is made. ———— 1-second interval; — — — — — — 2-second interval; - - - - - 3-second interval; ..... 5-second interval.

RESULTS

Reliability of Estimate of the Pre-stimulus Pulse Rate.—In order to determine the reliability of the measures of pulse rate in the pre-stimulus intervals, correlations were plotted to show the relationship between the pulse rates estimated from the first and second halves of the six-second pre-stimulus period. These correlations were calculated for individual sounds by using the two pre-stimulus counts for the given sound obtained for each subject tested. Similar correlations were obtained for the averages of all stimuli for each subject. The data for the correlations were obtained by finding the average

rate for the interval from 3 to 6 seconds and the interval from 0 to 3 seconds preceding the stimulus for each subject. The correlation of these averages is indicative of the reliability of the average changes for all stimuli used as discussed below. An examination of these correlations (see Table 2) shows that for individual sounds the pre-stimulus rate is reliable enough to permit its use as a measure of pulse rate from which deviations may be computed. These correlations range from .58 to .87 (median value .75). When the average of the two intervals of the pre-stimulus counts for eight sounds is used the correlation is .96 for girls and .93 for boys. When these correlations are adjusted by the Spearman-Brown formula it is evident that the determination of the pre-stimulus pulse level on the basis of a six-second count is reliable.

TABLE 2

RELIABILITY OF PRE-STIMULUS PULSE RATE COUNTS

Sound Stimuli			No Systematic Stimuli		
	Female	Male		Female	Male
	r*	r*		r*	r*
Loud snap	.75	.86	Sample I	.83	.79
Auto horn	.58	.82	Sample II	.87	.85
Cap pistol	.80	.64	Sample III	.93	.72
Siren	.58	.67	Sample IV	.89	.75
Gong	.80	.80			
Harmonic chord	.78	.63	Average of 4 estimates.	.96	.91
Tone frequency 145	.66	.61			
Tone frequency 307	.87	.76			
All stimuli	.96	.93			

* Raw Pearsonian coefficient of correlation.
Note: N varies from 36 to 45 for individual correlations.

Changes in Pulse Rate Following Auditory Stimuli.—Curves were drawn to show the average change in pulse rate at 3, 6, 9, 12 and 15 seconds after each sound stimulus. A study of these eight curves, samples of which are shown in Fig. 2, shows that the most consistent feature is a retardation in pulse rate which is maximal from 3 to 6 seconds after the presentation of the stimulus.

In order to determine whether the extent of pulse rate retardation is related to the degree of startle reported by the subjects, the average pulse rate change following the four stimuli rated as most startling by both boys and girls (spring snap, auto horn, cap pistol and fire gong) was compared with the average change following the four stimuli rated as least startling (siren, chord in A major, and the two musical notes with frequencies of 145 and 307). Figure 3 shows the

result of this analysis, from which it is concluded that on the average the pulse rate change is the same for the two groups of stimuli. This is not true of individual subjects, some of whom showed much greater pulse rate displacements to stimuli which they reported as startling than to those rated only slightly startling. Space does not permit discussion of these individual differences in the present report.

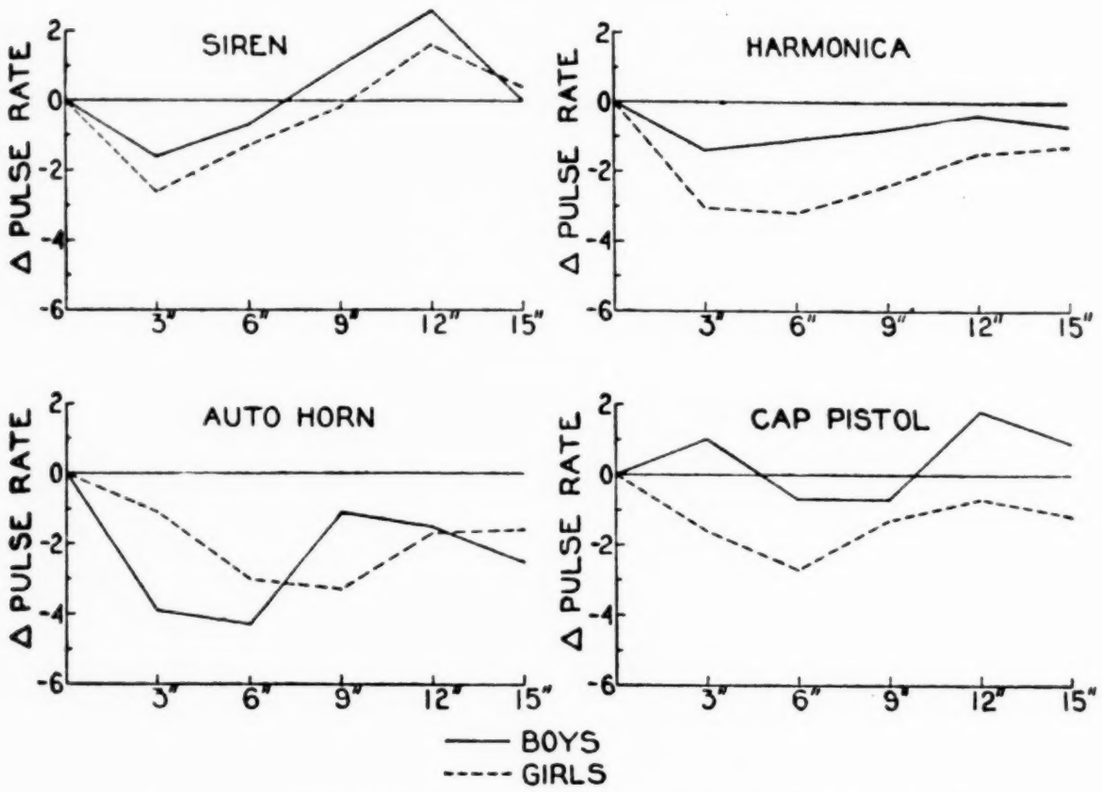

FIG. 2. Average pulse rate change following individual sound stimuli: ———— Boys; - - - - - - - Girls.

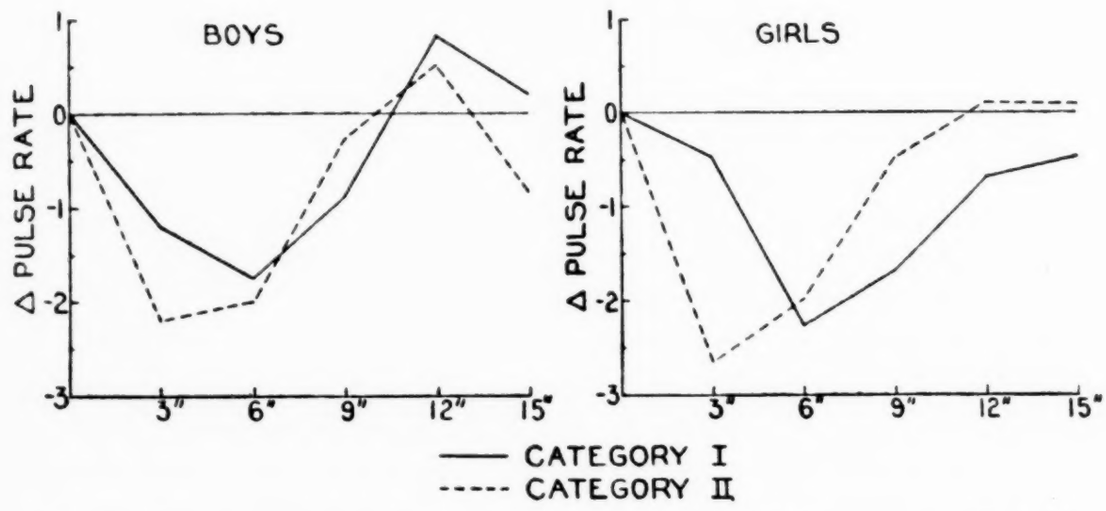

FIG. 3. Average pulse rate change following sound stimuli which were reported of different startle value: ———— Category I, four sounds rated least startling; - - - - - - Category II, four sounds rated most startling.

Since stimuli with different startle ratings showed no significant differences in pulse rate change the results from all eight sounds were averaged and plotted as shown in Fig. 4. Tests of statistical significance shown in Table 3 indicate that the average retardation of about two beats per minute which occurs from 3 to 9 seconds after the stimulus is real, since the critical ratios range from 4.3 to 5.2.

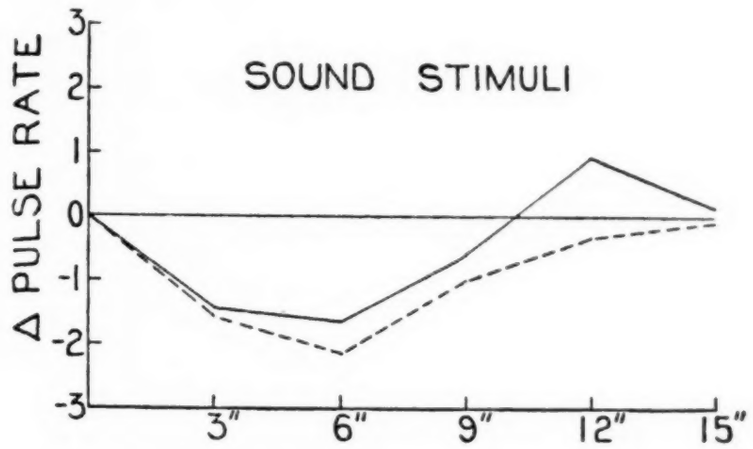

FIG. 4. Average pulse rate change following sound stimuli. ———— Boys; - - - - - - - Girls. (See text for complete explanation.)

TABLE 3

SIGNIFICANCE OF DEVIATION IN PULSE RATE FOLLOWING AUDITORY STIMULI

Interval.....	3"		6"		9"		12"		15"	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Mn. Dev.....	−1.57	−1.42	−2.16	−1.63	−.99	−.59	−.30	+.95	−.07	+.18
σ Mn.....	.36	.28	.42	.34	.33	.31	.42	.37	.40	.31
C. R.....	4.3	5.1	5.2	.47	3.0	1.9	.7	2.6	.2	.6
Sex Difference (Male − Female)										
Mn. Diff.....	+.15		+.53		+.40		+1.25		+.25	
C. R.....	.3		1.0		.9		2.2		.5	

Change in Pulse Rate without Systematic Stimulation.—In order to demonstrate the relation between pulse rate changes and the auditory stimulus, control observations on each subject were made by counting pulse rates in the same manner under conditions where no systematic stimulus schedule was administered. For this purpose records of pulse rate taken twenty-five minutes after running upstairs were used. Although the pulse rate under these conditions is still somewhat elevated over the basal resting levels, studies made in this laboratory have shown that the average decrease over a five-minute period is less than three beats. During this recovery period the sub-

ject was lying supine on a cot in a semi-darkened room without systematic stimulation. Four separate points were used as arbitrary reference or 'stimulus' points and estimates of pulse rate were made at 3, 6, 9, 12 and 15 seconds following in the same manner as before. These reference points were the beginning of the 25th, 26th, 27th and 28th minutes of the exercise experiments. Since no significant sex differences in pulse rate response were found, Fig. 5 shows the average

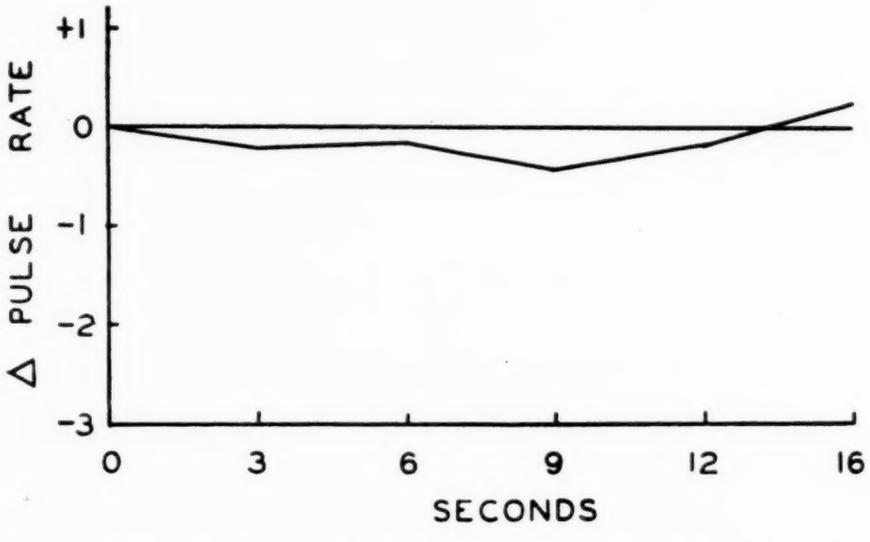

FIG. 5. Average pulse rate change when no stimulus was administered.

curve of displacement in pulse rate for boys and girls together. Statistical tests of significance give critical ratios less than 2.5 for all points of the curves (Table 4). This control experiment demonstrates clearly that the alterations in pulse rate reported are associated with the sounds that were presented and are not fortuitous fluctuations.

TABLE 4

SIGNIFICANCE OF DEVIATIONS IN PULSE RATE DURING LATE STAGES OF RECOVERY FROM EXERCISE

Interval.....	3″		6″		9″		12″		15″	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Mn. Dev.....	+.38	−.73	+.31	−.56	+.03	−.74	+.31	−.57	+.59	−.08
σMn.....	.55	.46	.57	.49	.51	.39	.55	.43	.62	.55
C. R.....	.7	1.6	.5	1.1	.1	1.9	.6	1.3	.9	.2
Sex Difference (Male − Female)										
Mn. Diff.....	−1.11		−.87		−.77		−.88		−.67	
C. R.....	1.5		.1		1.2		1.3		.8	

Discussion

The decrease in pulse rate following auditory stimuli must be explained in terms of the special conditions of our experiments. Most other experimenters have reported marked cardiac acceleration following startling emotional stimuli. In many of these experiments, such as those of Blatz (**5**), Springer (**19**), Ray (**15**), in which a falling chair was used as stimulus, a large amount of habitual motor activity followed the stimulus. This increase in muscle tonus, both abdominal and skeletal, would result in a sudden increase in the venous return to the heart, thus increasing the pulse rate (Bainbridge reflex) within one to three seconds after the stimulus. Since the stimuli used in the present study did not evoke any extensive muscular or respiratory response as shown by the kymograph records (Figs. 6 and 7) or notes of the experimenter, it is evident that the above mechanism was not activated and no cardiac acceleration was produced. Darrow (**8**) reported cardiac acceleration following sudden auditory stimulation, although greater acceleration was produced by association word stimuli. Lauer and Smith (**14**) reported an increase in pulse rate ranging from 6 to 9 percent following a bell, whistle, or rifle shot stimulus. The interval used in counting the pulse rate was not stated and no record of muscular movements on the part of the subject was made. Whitehorn, Kaufman and Thomas (**21**) used a Fleisch *Zeitschreiber* to obtain records of the duration of each individual heart beat and found that, with sudden startle stimuli, acceleration appeared within one beat. However, the data are scanty and in view of the irregularity of single beats which they report, little weight can be given to this finding. Skaggs (**17**) reports a slowing of pulse rate following an unexpected auto horn stimulus. His data on college students were analyzed by counting the total number of heart beats in the thirty seconds before the stimulus was given and the thirty seconds after the stimulus. This method does not permit any statement of rates of change. In a later experiment Skaggs (**18**) reports cardiac acceleration following a loud noise. In this experiment the subjects were anticipating a 'severe electric shock' when the horn was sounded instead, so that the conditions were not comparable with other experiments in which sudden auditory stimuli were used. In a study of 25 boys, aged 7 to 12 years, Ray (**15**) found an increase of pulse rate in 8 cases, a decrease in 13 and no change in 4 following the stimulus of a dropping chair. The motor activity produced in the boys was so great that Ray discarded the records obtained during the first five seconds after the stimulus and counted the number of heart beats between the fifth and twentieth seconds after the stimulus. This method of analysis also is inadequate for estimating the rate of change in pulse rate and may well obscure rapid shifts.

In our experiments the decrease in pulse rate appears within 3 to 6 seconds after the stimulus. Because of the longer intervals over which most experimenters have counted pulse rates it is impossible to tell whether a brief period of cardiac inhibition preceded the acceleration reported (Gaskill (**9**), Ray (**15**), Skaggs (**17**, **18**), Springer (**17**)). The experiments of Beebe-Center and Stevens (**1**), in which heart rates were estimated from single beats, showed a brief inhibition or slowing of the heart in cats immediately after a disturbing stimulus was presented and prior to the marked acceleration which followed. The speed with which the cardiac slowing appears in cats (less than 0.5 second) indicates a nervous mechanism, probably vagal. In another study of a gun-shy dog Beebe-Center and Stevens (**2**) reported an increase in pulse rate beginning with the first beat after the shot stimulus. Whitehorn, Kaufman and Thomas (**21**) reported that sudden startling auditory stimuli produced cardiac acceleration within one heart beat in mental patients. Thus it is apparent that the cardiac response to auditory stimuli may be influenced by the specific experimental situation. In a later study Berg and Beebe-Center (**4**) have concluded that the extent of the change in heart rate following a startling stimulus is affected by the phase in the respiratory cycle at which the stimulus occurred. We have found no such regular rhythm in pulse rates associated with respiration in adolescents as Berg and Beebe-Center report for their adults. In fact, the 'extrapolated heart rate' curves as reported in their study apparently show wide differences in reproducibility. We would be loath to make similar predictions from our material on adolescent children, where the variability in pulse rate is apparently even less predicatable (on a cyclic basis) than in adults. Because of the large number of stimuli administered and the substantial number of subjects considered in one study, we believe that it is safe to assume that the stimuli were not administered at any uniform point in the respiratory or cardiac cycle. Thus, any systematic differences in pulse rate response which we found associated with the character of the stimulus would be all the more significant.

It is possible that the slowing in the heart rate which we have found can be explained on the basis of the carotid sinus mechanism activated by a rise in blood pressure which would result from a general peripheral vaso-constriction after a sudden stimulus. Unfortunately continuous records of blood pressure change are not available in our data, so that this hypothesis cannot be investigated from the present data. We believe that the presence of cardiac acceleration reported by other experimenters is closely associated with superimposition of muscular responses in their experiments.

Although Cannon (**6**, **7**) has stressed the significance of the sym-

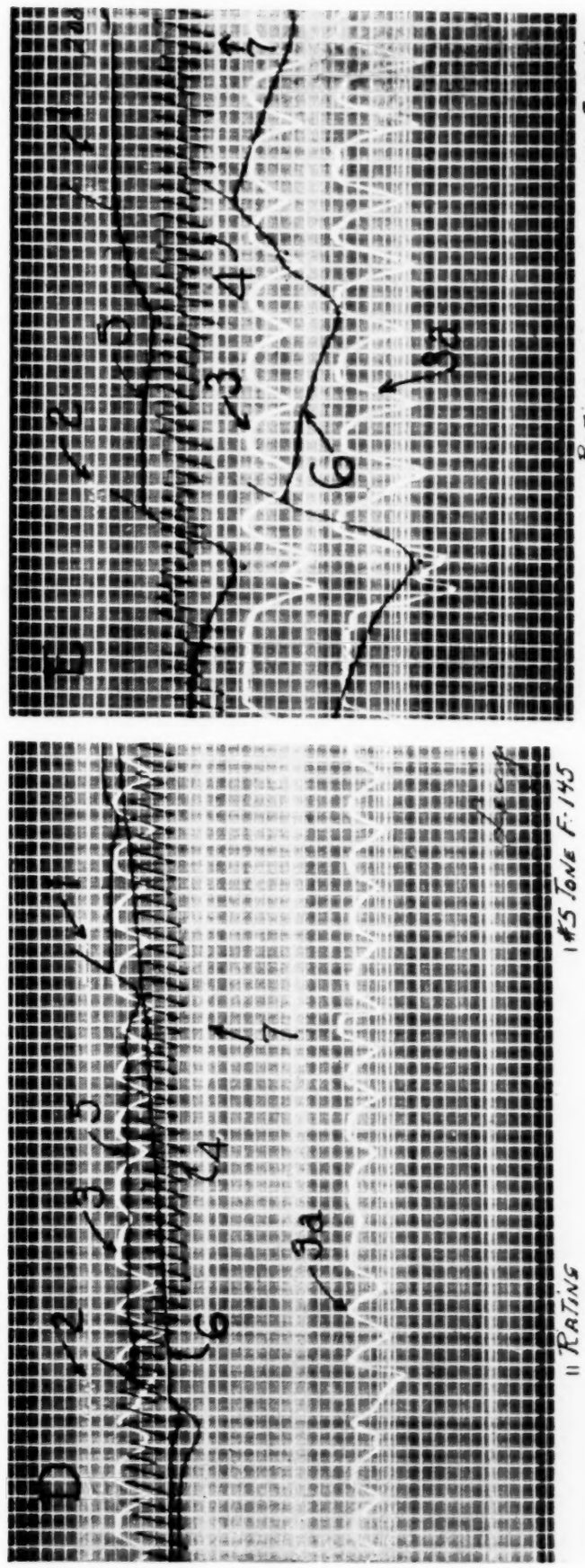

FIG. 6. Sample section from polygraph records showing absence of bodily movement or alterations in respiration when sound stimuli were presented. (Read from right to left.) 1—indicates time when sound was presented; 2—indicates time when rating was vocalized by subject; 3—respiration record from thoracic pneumograph (white line moves down with inspiration); 3-a—respiration record from abdominal pneumograph; 4—pulse rate record; 5—changes in skin resistance of right hand; 6—change in skin resistance of left foot; 7—electrical recorder attached to bed spring. Note absence of movement of 7 which indicates immobility of subject when stimulus was administered. Also note regularity of respiration curves when stimulus was given. Changes of respiration with vocalization are clearly shown at 2 *D*.

pathetico-adrenal discharge in emotion, latter studies by Kling (**13**), Bekhterev (**3**), and Von Bergmann (**20**), have found evidence that, at least in the human being, vagal discharges frequently accompany emotional processes. Gellhorn, Cortell and Feldman (**10**) have shown experimentally in cats that when central discharges through the sympathetico-adrenal system are eliminated by section of the cervical spinal cord, a *fall* in blood sugar follows stimulation of the cat by a barking dog. Since sectioning of the vagi below the diaphragm abolishes the fall in blood sugar, these authors believe that the emotional response is characterized by a simultaneous discharge over both vagal and sympathetico-adrenal systems. In the present experiment it is probable that conditions were such that the vagal response predominates. The immediate effect is a reduction in heart rate.

Summary

Changes in pulse rate following auditory stimuli have been recorded in a group of 45 girls and 47 boys with an average age of 14 years. Eight sound stimuli, consisting of a harmonic chord, siren, pistol shot, gong, and two tones, were presented to the subjects and ratings of pleasantness-unpleasantness as well as degree of startle produced were obtained.

Pulse rate was recorded photographically from a pneumatic cuff attached to the ankle of the subject. Preliminary analysis showed that changes are missed if the pulse rate is counted over ten- to fifteen-second intervals, but that a three-second interval is satisfactory for demonstrating rapid changes in rate. Reliability of reading the pre-stimulus levels of pulse rate was found to be 0.96 for girls and 0.93 for boys.

Sound stimuli produced a decrease in the average pulse rate of three beats per minute between 3 and 6 seconds after presentation of the stimulus with recovery by 12 to 15 seconds. The magnitude of the displacement in pulse rate was not significantly related to degree of startle reported by the subject under the conditions of this experiment.

(Manuscript received October 1, 1941)

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A FURTHER STUDY OF THE RELATION BETWEEN SKIN TEMPERATURE AND CUTANEOUS SENSITIVITY

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From the psychological laboratory of Sophie Newcomb College

INTRODUCTION

In an attempt to establish something of the nature of the reception of cutaneous stimuli, it was hypothesized, by the present writer (4), that a stimulus impinges upon a cutaneous receptor and there sets up a chemical reaction which in turn gives rise to the neural impulse leading to the mediation of a sensation. If this were true, that is, a chemical reaction were involved in the reception of a cutaneous stimulus, then it seemed probable that raising skin temperature should have the effect of increasing sensitivity or lowering thresholds.

In an earlier study (4) it was found that thresholds for vibratory sensations behaved according to the previously mentioned predictions. There was, however, one phenomenon observed which necessitated further assumptions if one were to adhere to a chemical theory. This was the fact that after thresholds dropped with increasing skin temperature a minimum was reached after which, with continued heating, there was a rise in these vibratory thresholds. An explanation of this was considered and will be discussed later.

From these findings on vibratory sensitivity, and similar results reported by Allers and Halpern (1) on pressure sensitivity, although they interpret their results as being due to mechanical changes in the skin, it seemed advisable to determine whether or not the phenomena would occur in other forms of cutaneous sensations. This investigation was thought especially necessary in view of the opinion that vibratory sensitivity and pressure sensitivity are mediated by the same receptors. Consequently the present study was undertaken, namely the effect of temperature on pain sensitivity, in order to determine whether or not the effect is the same as that found in the case of pressure and vibration, and if this were established then perhaps some general chemical scheme could be evolved for all of skin sensitivity.

[1] The author wishes to express his appreciation to Miss Janet Schneider for her assistance.

Apparatus.—The pain stimulus used in the present investigation was a single break shock from a Harvard inductorium, supplied by a 6 V. dry cell. The stimulating electrode was 1 mm in diam. The inductorium was calibrated with a cathode ray oscillograph. This was done by measuring the peak voltage on the oscillograph for various positions of the secondary coil over the primary. It was found that the inductorium had a linear scale so that measurements could be made in terms of the position of the secondary coil. No attempt was made to translate these readings into volts.

The changing of skin temperature was accomplished by means of a radiant heater, cylindrical in form, the open end being 4½″ in diam. This was mounted on a stand so as to be adjustable with respect to the angle it made with the arm.

Skin temperature measurements were made with a thermocouple and a G–M Temperature Rise Indicator.

Procedure.—The procedure consisted of placing the subject's arm in an arm rest, which had above it, tunnel fashion, two metal shields with a space between. The shields were used in order to delimit the heated area. When the subject obtained a comfortable position the neutral electrode was placed in the subject's hand and taped there. However, in several trials the subject merely held this electrode and it should be mentioned that as far as the results of this work are concerned there was no differential effect when the electrode was held or taped to the hand. The stimulating electrode was mounted in a wooden rod ⅜″ in diam. and 6″ in length and was held by the experimenter on the dorsal surface of the forearm. When a 'spot' was obtained which gave a clear 'pain' or 'pricking' sensation to electrical stimulation without any pressure or kinesthetic tug component, the electrode was kept on the 'spot' and a normal intensity threshold was taken by the method of minimal change. As soon as this determination had been made the temperature of the skin, adjacent to the electrode, was taken. The electrode was never removed from the 'spot' for the duration of the experimental session on that 'spot.' The radiant heater was then turned on and successive threshold measurements were taken using only ascending series. After each threshold determination, skin temperature was measured as before. This procedure was continued until the subject reported that the heat was uncomfortable or fatigue had set in due to holding a relatively fixed position.

In this same way a series of 'spots' were tested on six subjects, five females and one male. The results are presented here in graphic rather than tabular form since it is in this form that the findings are more meaningful. The graphs are drawn plotting threshold (percent normal) against the rise in skin temperature. That is, normal thresholds would be indicated at 100 percent and normal skin temperature at 0° C.

Figure 1 is the graph of four different 'spots' on one subject (J.S.) and Fig. 2 are the curves obtained from single 'spots' on three different subjects. These curves are characteristic of all other subjects used. It is apparent that here, as in the case of vibratory stimulation, a U-shaped curve is obtained.

It should be mentioned that there was one reversal found on one 'spot.' The thresholds for this 'spot' decreased in the usual way with increased skin temperature but after starting to rise one measurement showed a drop in threshold from the previous measurement; however, with continued heating the following threshold determinations showed the continuous rise from this point on. This was the only case of such a deviation.

In contrast to the curves found in vibratory sensitivity there is much less agreement among the present curves. From these data the optimal temperature for pain thresholds might be most anywhere ranging from 2½° to 9° above normal, whereas in the curves on pressure and vibration there was apparently a fairly fixed limit of tem-

perature range at which the low point of the curve would occur. This variability of the pain curves may be indicative of a great many different receptors for pain, all responding, in general, the same way, but perhaps having different chemical compositions.

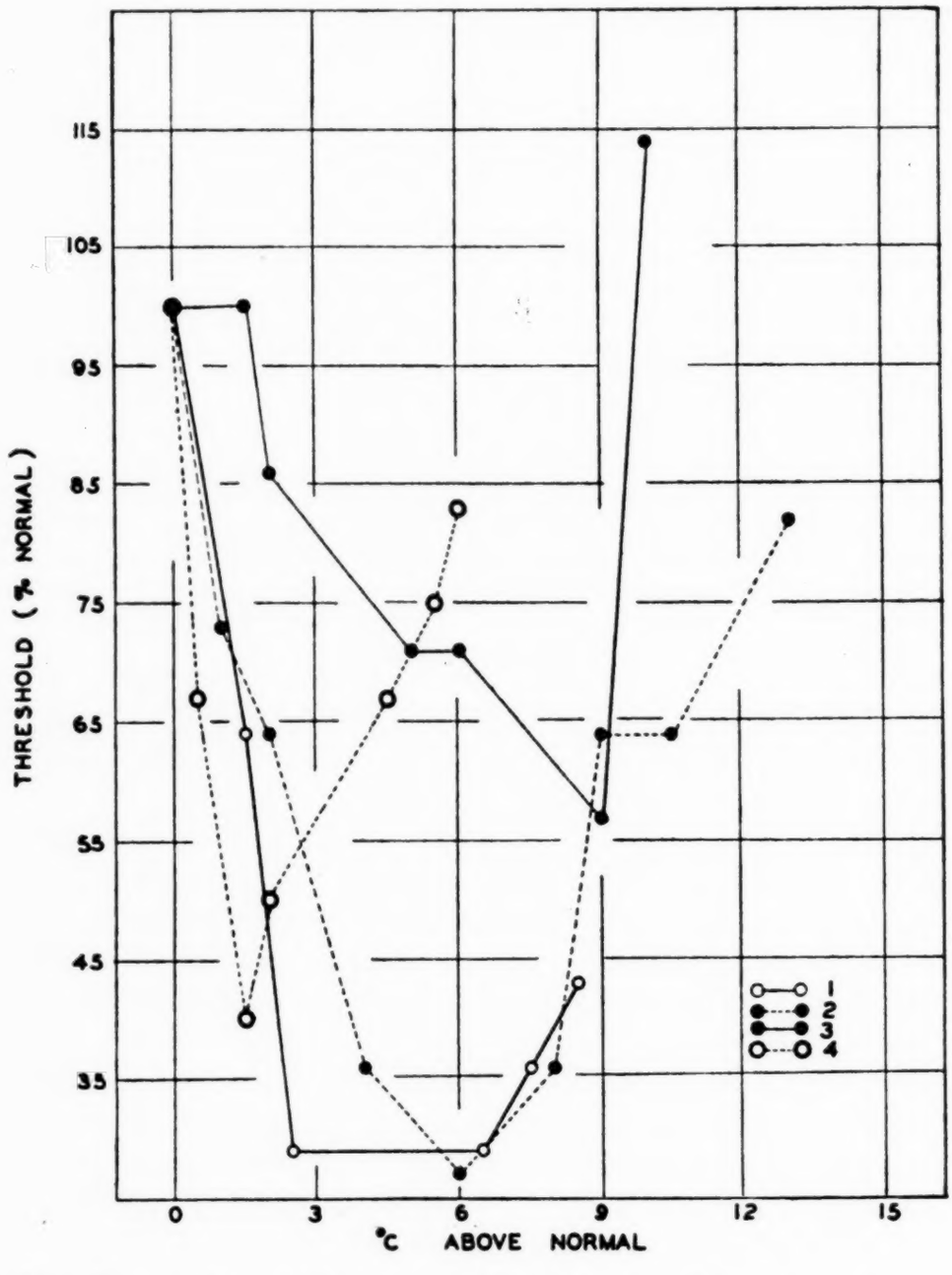

FIG. 1. The effect on pain sensitivity of warming the skin. Four different 'spots' on one subject.

THEORETICAL

The problem now arises of interpreting the results. Here we find the first part of the curve, namely the drop, fitting in with our earlier assumption, of the stimulus setting up a chemical reaction which, under conditions of increased temperature, takes place more rapidly.

However, here again, this does not explain the subsequent rise in thresholds.

In order to insure that this rise was not merely an effect of fatigue setting in, a series of thresholds were taken under normal skin temperature on a given 'spot.' This series consisted of a greater number

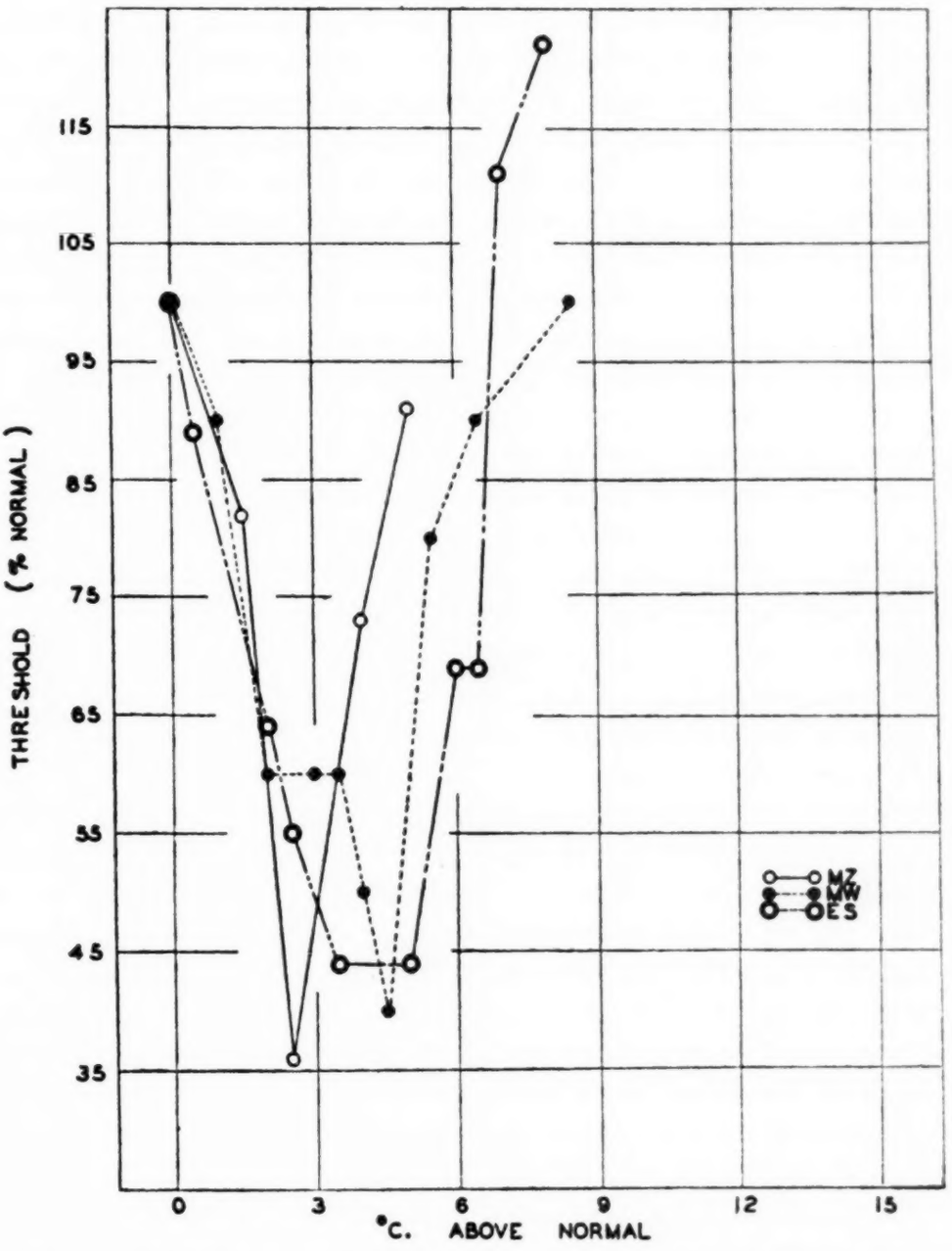

FIG. 2. The effect on pain sensitivity of warming the skin. Three subjects.

of threshold determinations than was made in any series involving warming the skin. It was found that successive threshold measurements showed very little variation from one measurement to the next. This, then, would eliminate the possibility of the increased pain limen being due to adaptation or fatigue.

Although from this control it would seem that fatigue was not the cause of the rise in thresholds there is the possibility that these changes taking place were due to some vascular action.

Nafe (**2**) has found that with a painful stimulus vasocontraction takes place. If it were hypothesized that this contraction mechanically stimulated the sensory endings in the vascular tissue and it was this stimulation which gave rise to the sensation 'pain' then one could easily explain the results of the present study on such a basis. This could be done in the following manner: With increasing temperature there is vascular dilatation, this dilatation would permit vascular contraction to take place much more readily upon painful stimulation so that a less intense stimulus would be necessary to evoke the required amount of contraction to lead to a sensation of pain. With increased heating the smooth muscle elements start to constrict and so a greater intensity of stimulation would be required to cause further contraction in order to reach threshold at a given 'spot' on the skin and hence the curve should rise. It can be seen that these assumptions fit nicely with the experimental findings.

In order to test this possibility one arm was placed in warm water and the contralateral arm stimulated electrically as before. If, now, the threshold variations were due to vascular changes then there should be some alteration of threshold with one arm in warm water since there is dilatation of vascular tissue of the contralateral member. Using water at 39.5°C., 40°C., 42°C., 43°C. and 46°C. there was no change in thresholds from the normal upon successive threshold measurements on a single 'spot.' However, this is a rather gross way of testing this assumption and probably more refined techniques should be used before one is positive that vascular changes are not the important factor. It would appear from this control, nevertheless, that the changes occurring in pain thresholds with increasing temperature were not due to concomitant vascular changes.

These controls would seemingly lead to the necessity of a chemical explanation. The rise in thresholds may be explained chemically under several different posibilities which the present writer proposed in the vibratory study. One is that the reaction is a catalytic one and this catalyst has an optimal temperature for operation. Here one would expect decreasing thresholds to a minimum (the optimal temp.) followed by a rise in the intensity necessary to evoke the sensation. Or, it is possible that the chemicals involved have, of themselves, an optimal temperature at which they will react; above and below this temperature the reaction time is increased. This is especially true of certain enzymatic processes. In the case of painful stimuli, Rosenthal and Minard (**3**) have found that histamine is released. Now, there is an enzyme which acts on histamine, known

as histaminase. If the joint action of these two chemicals is responsible for the production of a pain sensation then it would be reasonable to assume the previously mentioned effect of temperature on the chemical reaction, since an enzyme is involved.

Another possibility which seems more likely is that histamine alone is the chemical agent giving rise to pain. If there is a differential effect of temperature on histamine and histaminase, and since the action of histaminase on histamine is to destroy it, then there may be an optimal temperature for the production of histamine, and slightly beyond this temperature the action of histaminase is optimal thus destroying the histamine rapidly. Consequently, a greater intensity of stimulation would be required so as to allow a sufficient concentration of histamine to be present to evoke an impulse leading to pain. This explanation would fit the data obtained in the present investigation.

In order to test this histaminase could be introduced into the skin, electroendosmotically, perhaps, to determine whether or not thresholds were raised.

Summary and Conclusion

1. With increasing skin temperature, pain thresholds drop to a minimum, at which point, with further heating, they rise.

2. The function uniting pain and temperature is similar to that linking temperature and pressure, and temperature and vibration.

3. A chemical theory is suggested with a proposed plan of attack on the problem.

(Manuscript received September 5, 1941)

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A SIMPLE CUTTER OF CARDBOARD DISCS WITH OR WITHOUT CENTER HOLES

BY ROBERT CHENAULT GIVLER

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The disc cutter consists essentially of a rotating holder for a knife whose depth of cut may be adjusted by screws and whose radius of action by a bolt which permits a knife-bearing member to be slid along a rigid member and secured at the desired radial distance. The rotating member is operated by a crank whose vertical shaft pierces a hinged bridge and is fitted at its upper end with a compression spring in a collar to allow downward pressure on the knife and to insure its upward return.

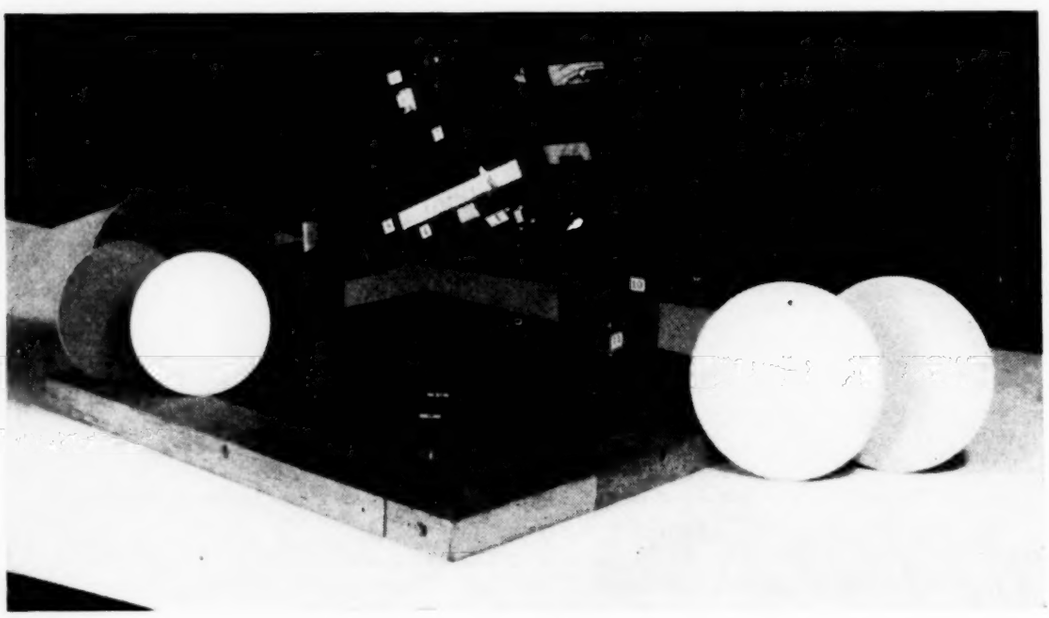

FIG. 1. Cardboard disc cutter.

To operate, a card of suitable size is fastened on a platten (in the picture glass tacks on extension springs are shown); the radius of the disc to be cut is determined by the calibrations on the rigid member, and the knife is so adjusted as just to touch the card when the free end of the bridge is pushed down into its socket and secured by a catch.

In the cutting operation care must be taken to rotate the knife slowly and at a constant rate, while the pressure on it must be very

gradually increased to prevent the knife from being displaced from its circular path through centrifugal force.

For cutting discs for use on the color wheel, the brass plate on the platten has a threaded hole directly in line with the axis of the vertical shaft, into which may be bolted a circular plinth of wood, over which fits the hole already punched in the cardboard for the purpose.

On the machine here shown (propped open to display its parts) discs of from 4″ to 8″ in diameter may be produced.

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